G. F. HELM

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SHORT SIGHT, LONG SIGHT

AND

ASTIGMATISM

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AN ELEMENTARY GUIDE TO THE REFRACTION OF THE EYE.

BY

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PREFACE

THE object of this book is to place before Students and Practitioners an elementary treatise on the errors of refraction of the eye, and to endeavour to explain in simple language their nature and the means whereby they may be satisfactorily corrected.

It is thus intended to serve as an introduction to the more advanced manuals on the same subject.

I regret that I am compelled, having in view the scope of the book, to omit all reference to the valuable aid which the direct Ophthalmoscopic Examination and Retinoscopy afford us in estimating and correcting errors of refraction.

To Mr Lang, Ophthalmic Surgeon to the Middlesex Hospital, I am much indebted for many valuable suggestions.

June 1st, 1886.

CONTENTS

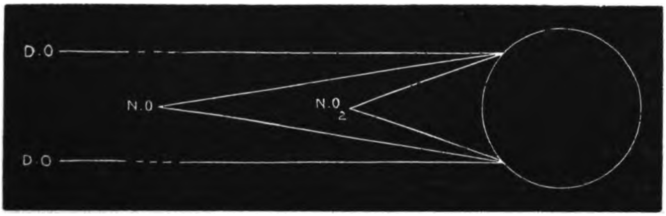
REFRACTION

CHAPTER I

LIGHT

1. Rays of light proceeding from an object which is situated at a distance of 6 metres (1 metre = 39·37 inches nearly) or more from the observer are considered as proceeding from that object in parallel lines, and therefore they fall upon the eye of the observer as parallel rays of light (Fig. 1).

Fig. 1.



D. O. = Parallel rays from a distant object.
N. O. = Diverging rays from a near object.
N. O_2. = Rays of increased divergence from a nearer object than N. O.
1 inch = 1 metre.

2. Rays of light proceeding from an object which is situated at a distance of less than six metres from the observer are considered as proceeding from that object in lines which *diverge,* and therefore they fall upon the eye of the observer as diverging rays of light (Fig. 1).

3. The amount of this divergence *increases* the nearer the object is brought to the eye of the observer, therefore the nearer the object is to the eye of the observer the more divergent is the direction in which the rays from it will fall upon his eye (Fig. 1).

4. The amount of divergence of the rays *decreases* the further the object is removed from the eye of the observer, and when the object has been removed to a distance of 6 metres or more the rays proceeding from it are considered as being parallel.

5. Therefore a *distant object* is one which, being situated at a distance of 6 metres or more, has rays of light proceeding from it in parallel lines.

6. A *near object* is one which, being situated at a distance of *less* than 6 metres, has rays of light proceeding from it in diverging lines, such lines becoming more and more divergent the nearer the object is brought to the eye of the observer.

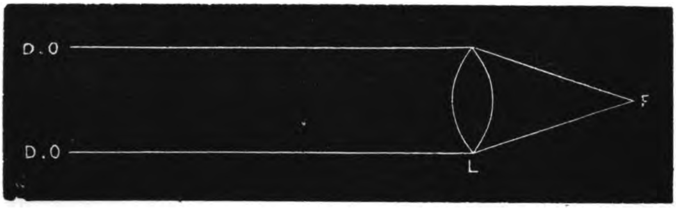
7. Spherical lenses are either biconvex or biconcave. Biconvex lenses are called + lenses. Biconcave lenses are called — lenses.

8. Rays of light when passed through a spherical lens or through a prism have their direction altered. They are then said to have been refracted by the lens or by the prism.

9. Supposing that parallel rays of light from a distant object are passed through a + lens (L, Fig. 2) the rays then become refracted and are brought to a point at F, and are said to be focussed at F.

This point F is therefore called the *principal focus* of the lens L (Fig. 2).

FIG. 2



D. O. = Distant object. L. = Lens. F. = Focus.

10. Rays of light passing through a spherical lens or a prism are always refracted towards the thickest part of the lens or prism.

11. The distance between the + lens and its principal focus (F, Fig. 2) will depend upon the degree of convexity of the lens.

12. If the distance between the + lens and F is 1 metre then the lens is called a lens of 1 metre focus, that is, it is a lens which will bring parallel rays to a focus at a point 1 metre distant from the lens.

Such a lens is taken as the unit for calculation, and is called a lens of 1 dioptre, or shortly + 1 D. spherical lens.

13. If the distance between the lens and F is only ½ metre, it is evident that a lens which can bring parallel rays to a focus at a point ½ metre distant from

it must be a lens of twice the refracting power of that lens which focusses similar parallel rays at a distance of 1 metre.

Hence, a lens whose focus is ½ metre (50 cm.) distant is called a lens of 2 dioptres or + 2 D.

14. If the distance between the lens and the focal point F is ⅓ metre then the lens has three times the strength of that lens which requires a length of 1 metre between it and F. Thus :

A lens of 1 dioptre focusses parallel rays at a distance of	.	.	1 metre or 100 cm.
A lens of 2	,,	,,	½ metre or 50 cm.
A lens of 3	,,	,,	⅓ metre or 33 cm.
A lens of 4	,,	,,	¼ metre or 25 cm.

15. Hence it follows that the distance between the lens and its focus, or its focal distance, can always be found by dividing 1 metre (=100 cm.) by the number of dioptres of the lens. Thus :

$\frac{100\text{ cm.}}{1\text{ D.}}$ = 100 cm. = 1 met. = focal distance of + 1 D. lens.

$\frac{100\text{ cm.}}{2\text{ D.}}$ = 50 cm. = focal distance of + 2 D. lens.

$\frac{100\text{ cm.}}{3\text{ D.}}$ = 33 cm. = ,, ,, of + 3 D. lens.

$\frac{100\text{ cm.}}{4\text{ D.}}$ = 25 cm. = ,, ,, of + 4 D. lens.

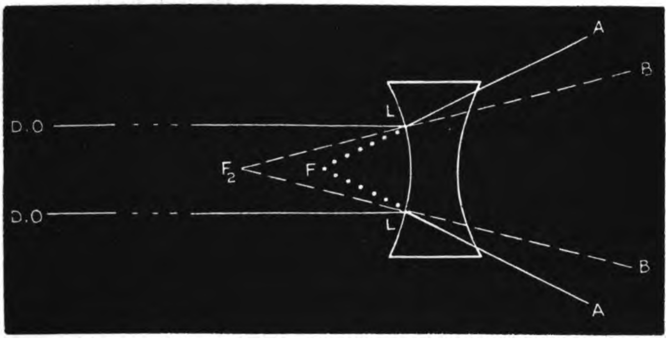
And so on.

16. Therefore the higher the number of the lens in dioptres the greater is its power of refracting rays of light which pass through it, and so the lenses +

2 D. + 3 D. + 4 D., have respectively twice, three times, and four times the power of a lens of + 1 D.

17. If the rays of light pass through a biconcave or — lens they are refracted (in accordance with S 10) towards the thickest part of the lens (Fig. 3).

FIG. 3.



D. O. = Parallel rays of distant object. L. = Lens.

Thus, parallel rays from a distant object, D O, passing through a — lens, L, would be refracted towards A, the thickest part of the lens, and the focus (F) would be situated on that side of the lens on which the distant object lies, *i. e.* between the object and the lens. And it would be at that point at which the diverging rays, A, would meet if they were continued backwards towards the object; and such a focus is called a *virtual* focus.

18. Hence the more divergent the rays are after their passage through the — lens the nearer will F be

to the lens, and the more powerful is the lens; a lens of lesser power would cause the rays to diverge to a lesser extent, and consequently, if continued backwards, they would meet at a point more remote from the lens.

In Fig. 3 let the parallel rays from D O be refracted into the direction of the lines L A.

Then, the lines A L, when continued backwards, would meet at F, which is consequently the virtual focus of the lens.

But if the rays were refracted to a lesser extent so as to take the direction of the lines L B, then the lines B L when continued backwards would meet at F_2, which in this case would be the virtual focus of the lens, and this lens would in that case be a less powerful — lens than one is which would have its virtual focus nearer to the lens than F_2.

19. Therefore, in speaking of — lenses, the greater the *divergence* given by them to parallel rays the more powerful is the lens; and in speaking of + lenses the greater the *convergence* given by them to parallel rays the more powerful is the lens.

If parallel rays are passed through a biconcave or — lens of — 1 D. they would diverge to such an extent that such rays would meet at a point F, situated on the *same* side of the lens as is the object, and the point F (*i. e.* focal point) would be at a distance of 1 metre from the lens.

20. Hence (1) a — lens of 1 dioptre has its virtual focus for parallel rays at a distance of 1 metre from the lens and on the same side of it as is the object.

(2) A lens of $-$ 2 D. has its focus at $\frac{1}{2}$ metre or 50 cm. and on same side as is the object.

(3) A lens of $-$ 3 D. has its focus at $\frac{1}{3}$ metre or 33 cm. and on the same side as is the object.

(4) A lens of $-$ 4 D. has its focus at $\frac{1}{4}$ metre or 25 cm. and on the same side as is the object. And so on.

21. And the focal distance of a $-$ lens is found in exactly the same way as the focal distance of a $+$ lens is found (*vide* **15**) by dividing 1 metre (100 cm.) by the number of the dioptres of the lens. Thus:

$\frac{100 \text{ cm.}}{-1 \text{ D.}}$ = 100 cm. = 1 metre = focal distance of $-$ 1 D.

$\frac{100 \text{ cm.}}{-2 \text{ D.}}$ = 50 cm. = focal distance of $-$2 D.

$\frac{100 \text{ cm.}}{-3 \text{ D.}}$ = 33 cm. = „ „ of $-$3 D.

$\frac{100 \text{ cm.}}{-4 \text{ D.}}$ = 25 cm. = „ „ of $-$4 D.

22. Diverging rays of light proceeding from a near object (**2**) and passing through a $-$ lens, will be refracted more than parallel rays passing through the same lens would be, because coming from a near object they are already divergent rays before they meet the $-$ lens, which causes them to diverge still further.

Important points to be remembered are:

23. That rays proceeding from an object placed at a point which is at the same distance from a $+$ lens as is its focal point, will emerge from such a lens as parallel rays (Figs. 4 and 5).

24. That rays proceeding from an object placed at a point which is *beyond* the focal point of a lens will emerge from that lens as *converging* rays (Fig. 6).

25. That rays proceeding from an object placed at a point which is *within* the focal point of a lens will emerge from that lens as *diverging* rays (Fig. 7).

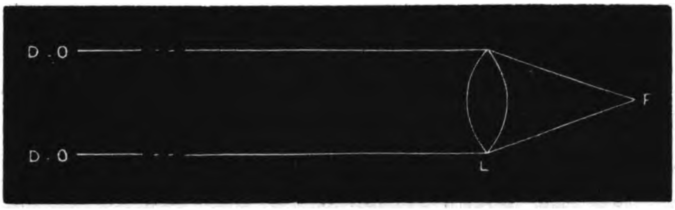
It has been mentioned before that parallel rays from a distant object passing through a + 1 D. lens are focussed at F distant 1 metre from the lens (Fig. 4).

26. But if the object be placed at the point O (Fig. 5) the same distance from the + 1 D. lens that the point F is, say a distance of 1 metre, then the rays of light from O would pass out of the lens as parallel rays, because the point O is situated at the exact focal distance of the + 1 D. lens (Fig. 5).

27. Thus, parallel rays of light (Fig. 4) meet at F, and diverging rays of light from an object at F would pass out of the lens as parallel rays (Fig. 5).

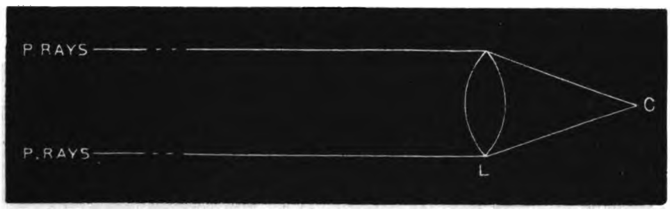
28. But if the object be removed further away (Fig. 6) from F the focus of the + 1 D. lens (*i. e.* to a distance beyond 1 metre) the rays of light from it would no longer pass out of the lens as parallel rays, but as the object receded gradually further and further away from F so would the rays of light pass out of the lens as more and more converging rays; and when the object had arrived at a point O (Fig. 6), distant 2 metres from the + 1 D. lens (*i. e.* to a point at *double* the focal distance of the lens) they would have converged sufficiently to meet at the point F_2, which is distant also 2 metres from the lens.

Fig. 4.



D. O. = Distant object. L. = Lens. F. = Focus.

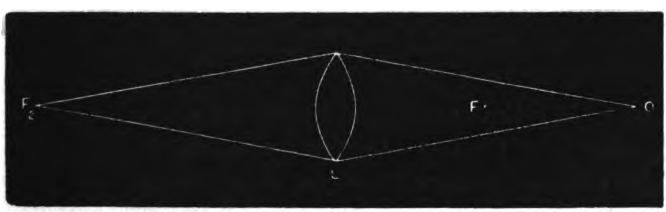
Fig. 5.



O. = Object situated at the same distance from the lens that the focal point of the lens is.

P. R. = Parallel rays.

Fig. 6.



F. = Point which would be the focus of parallel rays passing through L.

O. = Object at double the focal distance of the lens L.

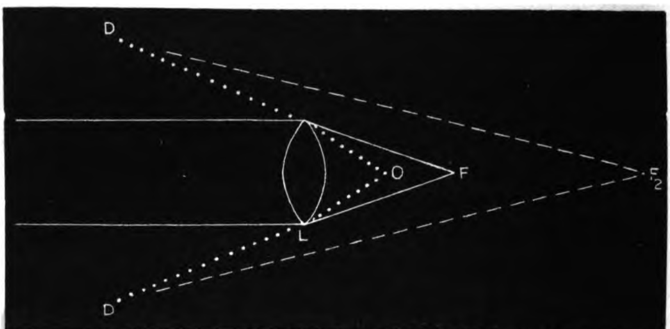
F_2. = Conjugate focus of object at o.

29. Hence, whenever the object is situated at double the focal distance of the lens, the focus of that object will also be situated at double the focal distance of the lens, but on the other side of it as at F_2 (Fig. 6). And an object at F_2 would be focussed at O (Fig. 6). So that in such a case the object and its focus can be transposed.

30. The points F_2 and O are therefore known as conjugate foci.

31. But if the object, instead of being placed beyond the focal point F of a + 1 D. lens, be now placed as at O, Fig. 7, a point *within* the focal distance, F, of the

FIG. 7.

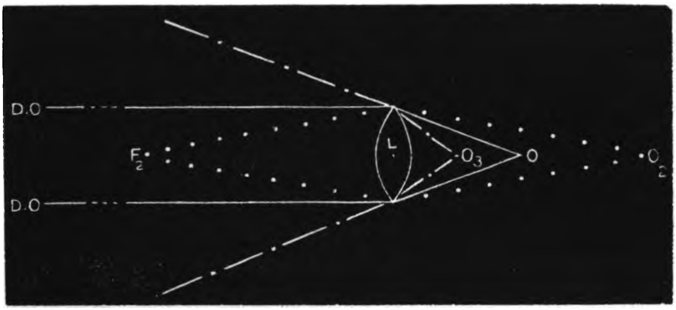


O. = Object placed within focal distance of the lens.
F_2. = Virtual focus of O.

lens, then the rays proceeding from O, a point *nearer* to the lens than is the point F, would fall upon the lens as much more divergent rays than if they had come from the more distant point F, and consequently the lens is not equal to refracting them even into parallel rays as it would do if they came from the focus,

but they would emerge from the lens as diverging rays at D and would be lost in space, and their focus would be a virtual one on the same side of the lens as that on which the object is situated, say at F_2 (Fig. 7).

FIG. 8.



To recapitulate—

A. Let L be a + lens with its focus at O (Fig. 8). Then the rays from an object at O will emerge from the lens as parallel rays (D O).

B. Let O_2 be an object situated outside (*i. e.* beyond) the focal point O, and let it be at double the distance from L that O is. Then the rays from O_2 having passed through L will be focussed at its conjugate focus F_2 (30).

C. Let O_3 be an object situated inside (*i. e.* within) the focal point O. Then rays proceeding from an object at O_3 after having passed through the lens will emerge from the lens as diverging rays. Thus:

Rays from O the focus emerge from the lens as parallel rays.

Rays from o_2 outside the focus emerge from the lens as converging rays.

Rays from o_3 inside the focus emerge from the lens as diverging rays.

But if the object be gradually moved from o_2 so as to approach the lens, then, in proportion as the object approaches o, so will the rays from it tend to gradually assume on the other side of the lens the same direction as they would have if they had come from o, and as o is the focus that direction would be parallel. And when the object has arrived at o the rays from it will then pass out in a parallel direction, because o is at the same distance from the lens that its principal focus is.

And if the object be moved from o to a point still nearer to the lens, then in proportion as the object approaches the lens so will the rays from the object emerge from the lens with an increasing degree of divergence.

And, *vice versâ,* if we start the object from the point o_3 the rays from it at starting will emerge from the lens as diverging rays; and when the object has arrived at o the rays will have become parallel on the other side of the lens; and by the time that the object has arrived at o_2, the parallel rays on the other side of the lens will now have become converging with a focus at the conjugate focus F_2.

CHAPTER II

DEFINITIONS OF EMMETROPIA, MYOPIA, AND HYPERMETROPIA.

32. An eye in connection with refractiou may be considered as made up of:

(1) Certain refractive media (cornea, aqueous humour, lens), which together possess the same power of refracting rays of light as does a + lens.

(2) The retina on which the rays of light *should* be focussed after that they have passed through the refracting media.

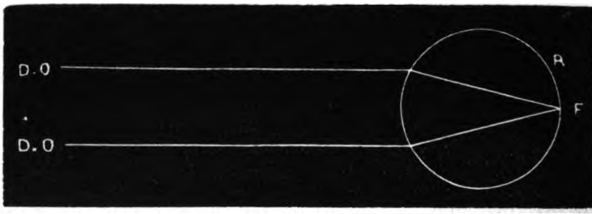
But it is not every eye that possesses this power of focussing *on* the retina the rays of light which have passed through the refracting media. That is, there exists in some eyes certain errors of refraction which prevent the rays of light from being focussed on the retina.

33. In order to compare errors of refraction in different eyes a certain standard of perfection is agreed upon.

A normally refracting eye is one which, when in a state of rest (with all efforts of accommodation in abeyance, and therefore acting like a simple refracting + lens) will focus on the retina the parallel rays proceeding from a distant object.

34. Such an eye is called an emmetropic eye (Fig. 9), and its possessors are called emmetropes.

FIG. 9.—Emmetropic Eye.

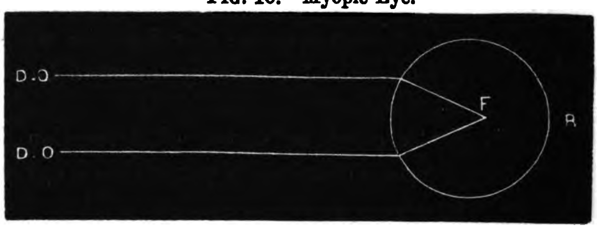


D. O. = Distant object, rays from which are focussed at F. on retina.
R. = Retina.

35. All eyes deviating from the above standard of perfection are called ametropic eyes. Ametropic eyes are of two kinds.

36. (A) An eye which, without any effort of the will (*i. e.* acting like a + lens) focusses *in front* of the retina instead of *on it*, the parallel rays from a distant

FIG. 10.—Myopic Eye.

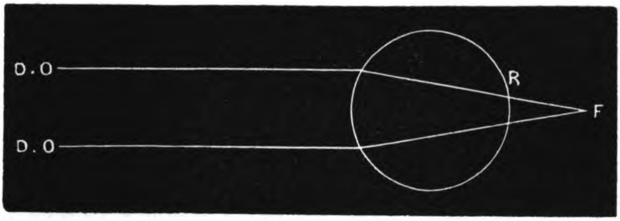


D. O. = Distant object, rays from which are focussed at F. in front of the retina.
R. = Retina.

object, is called a myopic eye (Fig. 10) and its possessor is the subject of *myopia*.

37. (B) An eye which, without any effort of the will (*i. e.* acting like a + lens), focusses *behind* the retina instead of *on* it, the parallel rays proceeding from a distant object, is called a hypermetropic eye (Fig. 11), and its possessor is the subject of *hypermetropia.*

FIG. 11.—Hypermetropic Eye.



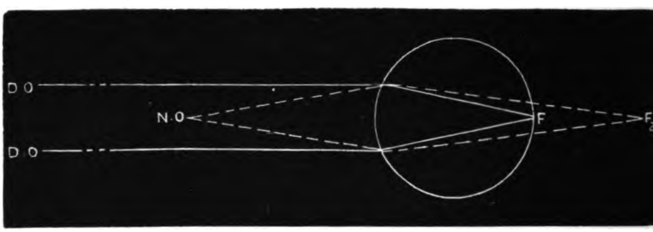
D. O. = Distant object, rays from which are focussed at F. behind the retina.
R. = Retina.

CHAPTER III

ACCOMMODATION

It has been shown (33) that the emmetropic eye when in a state of rest will focus on the retina parallel rays from a distant object, and vision of such an object would be distinct. It follows, therefore, that if the emmetropic eye continues in a state of rest, the diverging rays from a near object must be focussed behind the retina (Fig. 12) and vision of such an object would consequently be imperfect.

FIG. 12.



D. O. = Distant object, with parallel rays proceeding from it.
N. O. = Near object, with diverging rays proceeding from it.
F. = Focus for parallel rays.
F_2. = Focus for diverging rays from N O.

But supposing that the refracting media of the emmetropic eye were by some means to be made more

convex when looking at the near object, then the divergent rays from this near object *might* be focussed on the retina instead of behind it.

This is just what does take place when the emmetropic eye views a near object, for in the eye (whether emmetropic or ametropic) there *does* reside an ability to call into play an increase in its refractive power, whereby the eye which, at one moment, when in a state of rest, can obtain a distinct view of distant objects, can now at another moment suddenly view a near object.

But the eye is then considered as being no longer in a state of rest, for it accomplishes this vision of near objects by altering the shape and position of the lens, making the refraction of the eye for the moment more powerful, and therefore the diverging rays from a near object, which would have been focussed behind the retina, if the lens had retained the same shape as it had when viewing a distant object (Fig. 12) are now in consequence of the increased convexity of the lens, enabled to be focussed on the retina (**44**).

38. This voluntary alteration in the refractive power of the eye is called its power of accommodation.

CHAPTER IV

MYOPIA

We have seen (36) that a myopic eye is one which, in a state of rest (*i. e.* with no exercise of accommodation), focusses *in front* of the retina instead of on it, the parallel rays from a distant object.

39. This error of refraction might arise from three causes.

(A) The myopic eye may be too long in its antero-posterior diameter, *i. e.* from the cornea in front to the retina behind, so that the retina is removed too far back from the refracting media of the eye; thus leading to the focussing of the rays of light in front of it.

(B) The refracting media of the eye may be too convex, and so they bring the rays *too soon* to a focus, *i. e.* to a point in front of the retina.

(C) Too high an index of refraction of the *transparent* media of the eye.

40. Although some authorities doubt the existence of the cause (2 and 3), yet perhaps it may simplify future explanations if we regard the myopic eye as one which errs in having its refractive media too convex, since such a definition at once suggests the general remedy for myopia, viz. biconcave or — lenses.

41. It follows, from the definition of the myopic eye,

that such an eye is unable to see any object at a distance (6 metres or more) because it cannot focus on the retina the parallel rays. But if diverging rays are presented to a myopic eye, then the refracting media, which possess too much convexity for the focussing of *parallel* rays, may have such an extra amount of convexity as will focus on the retina rays of a certain amount of divergency, thereby giving distinct vision for them.

Yet, if the rays of light have too great an amount of divergency for the eye under consideration, then the rays would be focussed behind the retina, and vision would be again indistinct, unless accommodation is brought into use. So that in Fig. 13 the rays from D O (distant object) are focussed at F.

But the rays from N O (near object) have just that amount of divergency as will, so to say, fit the error of increased refraction of the eye under consideration, and they are focussed at F_2.

Suppose a book situated at N O, then this myopic eye would be able to read the type, and if the book is removed a little further *from* the eye than N O, then the rays of light would no longer be focussed on the retina at F_2, but just as the book was removed further off, so the focus of its rays would *recede* from the retina at F_2 and would gradually approach the point F. Of course, therefore, vision is indistinct directly the type begins to be removed further from the eye than N O.

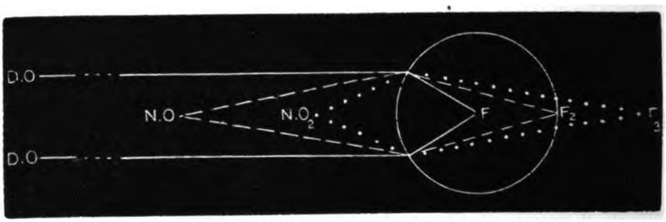
42. Hence N O is really the *farthest* point of distinct vision for this myopic eye.

43. The far point of distinct vision is spoken of as the punctum remotum, or p. r.

But suppose that the type, which this myopic eye can read distinctly when placed at N O, is now brought *nearer* to the eye than N O, *i. e.* towards N O_2.

44. Then, the nearer it is to the eye the further *behind* the retina is its focus, and vision would again

FIG. 13.



be indistinct unless the eye brought its accommodation into use, and if by using accommodation the type can be read at N O_2:

45. Then N O_2 would be the *nearest* point of distinct vision for this myopic eye.

46. The near point of distinct vision is spoken of as the punctum proximum, or p. p.

So that, to recapitulate—

47. In the emmetropic eye the far point of distinct vision is at an infinite distance, *i. e.* at a distance of 6 metres or more.

48. In the myopic eye the *far* point is at a finite distance, *i. e.* at a distance of less than 6 metres, varying according to the amount of the myopia.

49. That there is a *near* point of distinct vision both

in emmetropic and myopic eyes is the result of the exercise of accommodation.

50. But in the myopic eye, as the *far* point may be inconveniently near to the eye for reading, &c., of course the near point would be still more inconvenient for any practical use.

51. Hence, in myopia of any extent, there is hardly any use for accommodation, consequently in myopia the ciliary muscle from disuse is usually atrophied.

52. The accommodation, therefore, in a myopic eye is defective from disuse, and if called into play it can only be exercised at the expense of great straining of the eye and other serious results.

Therefore, as we shall see further on, when remedying the myopia by means of spectacles we are always careful to select (except in cases of slight myopia in young subjects) such lenses as will in their use entail no effort of accommodation, with its attendant risks, in highly myopic eyes.

53. The degree of myopia is measured by the distance which the punctum remotum is from the eye.

54. If it is distant 50 cm., then the eye has 2 dioptres of myopia.

$$\text{Because } \frac{100 \text{ cm. (1 metre)}}{50 \text{ cm.}} = 2 \text{ D.}$$

If it is distant 25 cm., then the eye has 4 dioptres of myopia.

$$\text{Because } \frac{100 \text{ cm.}}{25 \text{ cm.}} = 4 \text{ D.}$$

55. So that the further the distance of the punctum remotum from the eye the less is the myopia.

For it is evident that the eye which has its punctum remotum at 50 cm. will deviate less from the emmetropic eye (which has its punctum remotum at infinity) than does that eye which has its punctum remotum at only 25 cm. distance from the eye, and in the former case there is myopia of -2 D.

$$\text{Because } \frac{100 \text{ cm.}}{50 \text{ cm.}} = -2 \text{ D.}$$

And in the latter case there is myopia of -4 D.

$$\text{Because } \frac{100 \text{ cm.}}{25 \text{ cm.}} = -4 \text{ D.}$$

56. Because the error of refraction in myopia shows itself by the punctum remotum being at a finite instead of at an infinite distance, it follows, that the remedy will be to place in front of the eye such a lens as will push back the punctum remotum from a finite to an infinite distance.

Suppose that we have a case of myopia of 7 dioptres, which is equivalent to saying that the punctum remotum is at 14 cm. distance from the eye.

$$\text{Because } \frac{100 \text{ cm.}}{7 \text{ D.}} = 14 \text{ cm. (nearly).}$$

In other words, this eye in a state of rest can focus on the retina rays of light which have just that amount of divergence which those rays have which come from an object at 14 cm. distance.

Now, if a -7 D. lens be placed in front of this myopic eye, it will give to the parallel rays which come from an infinite distance just that exact amount

of divergence which they would have if they had come from the finite distance of 14 cm.—the distance at which there is distinct vision in this myopic eye.

$$\text{Because } \frac{100 \text{ cm.}}{14 \text{ cm.}} = -7 \text{ D.}$$

This eye can now, with a -7 D. lens, be considered as an emmetropic eye, with distinct vision for *distant* objects.

If this is the desire of a patient with myopia of 7 dioptres we have theoretically met his wishes by means of a -7 D. lens.

But in practice we find that a lens of -1 D. or $-1{\cdot}5$ D. less than -7 D. (*i. e.* -6 D. or $-5{\cdot}5$ D) would be most suitable because a -7 D. lens might possibly over-correct the myopia, *i. e.* the focus for distant objects, which was originally too far forwards in front of the retina, may possibly now, by means of the $-$lens, be pushed *too far back* so as to be behind the retina.

In such a case, the eye by exercising accommodation will bring the focus forward again and so put it on the retina instead of behind it.

But for reasons given in **52, 63,** one object to be aimed at in cases of myopia is to take care that accommodation is not called into play.

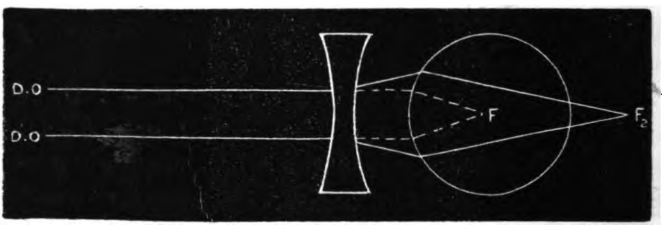
57. And, therefore, to ensure against over-correcting the myopia by means of any lenses, the rule is to give in such cases the *weakest* lens which will give distinct vision.

So that if the patient on being fitted with trial lenses has equally distinct vision for distant objects with a -5 D. or -6 D. or $-6{\cdot}5$ D. or -7 D.:

Then the − 5 D. would be the proper lens for distant vision, because it gives the greatest assurance against over-correction of the myopia with its consequent accommodative effort, which we so much wish to avoid in these cases.

58. To show what is meant by over-correcting the myopia, let Fig. 14 represent the parallel rays from a

FIG. 14.



D. O. = Rays from distant objects.
F. = Myopic focus of rays from D. O.
F_2. = Focus of the over-corrected myopia.

distant object, which would in this myopic eye be focussed in front of the retina at F.

But if they were passed through a too powerful − lens they would be rendered so divergent that they may be now focussed behind the retina at f_2, and indistinct vision would again result from the over-correction of the myopia.

But this patient, by using his accommodation, could bring the focus forwards again on to the retina, and notwithstanding the over-correcting lens he might say that his vision is distinct. If it is so, he must have been using his accommodation.

59. In order then to test whether, in making this statement of distinct vision, he has been using his accommodation, we test him with a — lens of less power. Perhaps he will still state that he sees correctly—in that case he has been using his accommodation to a lesser extent than he did when tried with the more powerful lens.

So we gradually reduce the power of the trial lenses (and each reduction, if accompanied by a statement of clear vision, means therefore a corresponding diminution of the accommodation used) till we come to a lens with which vision is no longer distinct, *i. e.* the accommodation has been dropped as being no longer of any use, and we have brought the focus back to a point in front of the retina.

We then revert to the *weakest* lens, which gave distinct vision, and feel sure that the patient's accommodation is not being used with it. For the difference between the strongest (over-correcting) lens and the weakest lenses with which vision was distinct, must clearly represent the power of the accommodation used.

60. But most myopic patients require something more than distinct vision for *distant* objects. They require to be able to read, write, work, &c., at greater distances from their eyes than their natural far point of distinct vision will allow them to do.

61. This of course applies to cases of high myopia, for where the myopia is slight, say of -3 D or even -4 D the natural far points would be

$$33 \text{ cm.} \left(\frac{100}{3\text{ D.}} = 33 \text{ cm.}\right) \text{ and } 25 \text{ cm.} \left(\frac{100}{4\text{ D.}} = 25 \text{ cm.}\right)$$

respectively, at which distances reading can be carried on at no inconvenience as far as the distance of the book is concerned.

Glasses for distant vision only might be required in such cases.

62. But where the myopia is of high degree it may at first be thought that the lens which fully corrects the myopia for distant objects, would be a proper lens for near objects, because the fully-correcting lens would have made the myopic eye into an emmetropic eye, and an emmetropic eye can see near objects.

63. But it sees near objects by exercising its accommodation, and in myopia there are two objections to depending on accommodation for vision of near objects.

(A) "The fact that in myopia the ciliary muscle is wasted and hence there is deficient accommodation, whereas a fully correcting lens requires full accommodation for near vision, and since in myopia the power of accommodation is weakened from disease of the ciliary muscle, overstraining of the eye would result and so cause discomfort, if nothing worse.

(B) "By a fully correcting — lens the retinal images would be so much diminished in size that the patient is tempted to enlarge the images again by bringing the object nearer, thus doing away with much of the benefit which his lenses ought to bring to him." (*Nettleship.*)

64. Hence in higher degrees of myopia we require for distinct *near* vision such a lens as will place the

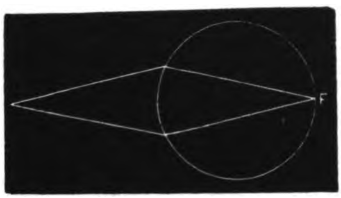
far point at a greater distance from the eye than at which the natural refraction of the eye places it.

Suppose that we are dealing again with an eye which possesses 7 dioptres of myopia, such an eye will have its far point at 14 cm. from the eye—

$$\left(\frac{100 \text{ cm.}}{7 \text{ D.}} = 14 \text{ cm.}\right).$$

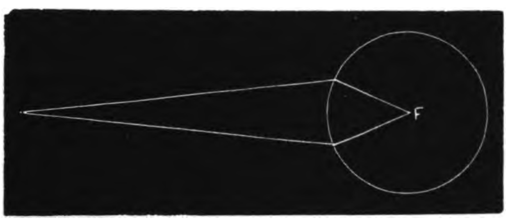
Let us suppose that we require to remove this far point to a distance of 30 cm. (*vide* Figs. 15, 16, 17).

FIG. 15.



Diverging rays from 14 cm. focussed on retina.

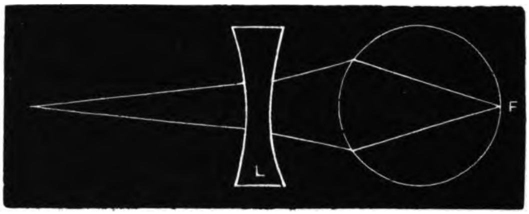
FIG. 16.



Less diverging rays from 30 cm. focussed in front of retina.

Rays coming from an object at 30 cm. distance will have *less* divergence than they would have if they came from an object 14 cm.

FIG. 17.



Increased divergence given by means of lens to rays from 30 cm., so as to give them the same amount of divergence as they would have if they came from 14 cm.; consequently they are focussed on the retina, and the far point is 30 cm. instead of 14 cm.

Now, an eye with 7 D of myopia has distinct vision for an object distant 14 cm., because that is its natural far point.

Hence what we require is to give to the less diverging rays from 30 cm. such an increase in their divergence as will make them appear as if they came from a distance of 14 cm.

That being done these rays from 30 cm. are now properly focussed and distinct vision at that distance results.

Now, a — 7 D. lens (which is the fully correcting lens in this case) will give to the parallel rays such an amount of divergence as they would have if they came from a distance of 14 cm.

But we require to give to the rays a less amount of divergence than that; we only require that they should have the lesser divergence of an object at 30 cm.

Therefore from such a lens as has a focal distance

of 14 cm. (— 7 D.) we subtract that lens whose focal distance is 30 cm. (— 3·25 D.).

Our sum will stand thus:

$$\begin{array}{r} -\ 7\ \text{D.} \\ \underline{-\ 3{\cdot}25\ \text{D.}} \\ -\ 3{\cdot}75\ \text{D.} \end{array}$$

And a lens — 3·75 D. will be the lens required.

But the patient should be cautioned against using his spectacles to see objects situated at a shorter distance than that for which they are adapted (30 cm.) because in that case the divergence of the rays from the object are increased the nearer it is brought to the eye, and such rays would be focussed behind the retina, producing confused vision, though by using his accommodation distinct vision would be restored, but the use of accommodation, we have before said, is hurtful, therefore the patient should take care to place his work at his allotted distance from the eye, though his difficulty in so doing is incressed by the fact that there is a constant temptation to overstep his distance, because the nearer the object is to the eye the larger is the image which he obtains on his retina.

Hence watchfulness and attention are required on the part of the patient.

65. To sum up then:

In young people in whom the myopia is not extreme, say — 2·5 D., and in whom in consequence of youth the ciliary muscle has not yet had time to become atrophied from disuse, we may in these cases supply lenses which fully correct the myopia for distant objcts.

In these cases we have no hesitation in calling upon their accommodation to supply them with distinct vision for near objects.

66. Also in the case of myopia of not above say — 7 D. occurring in persons not over twenty-five years of age, we may try fully correcting glasses, provided they show no signs of disease of the fundus of the eye. By giving them fully correcting glasses we rely on the accommodation coming into play and giving near vision. By wearing these fully correcting lenses constantly "the ciliary muscle may be coaxed into action, and may eventually be brought up to the normal working power." (*Lang.*)

67. In older people in whom the myopia is not extreme we may also give lenses which fully correct the myopia for distant objects, but with the caution that they should not be used for near objects.

Their myopia not being extreme, their natural far point (without lenses) will be situated at a convenient distance from the eye for reading, &c.

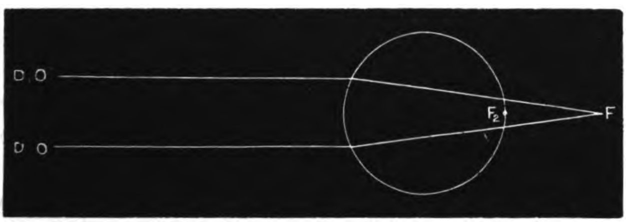
68. But in extreme myopia we give glasses in accordance with Section **64.**

CHAPTER V

HYPERMETROPIA

69. In the hypermetropic eye the parallel rays from a distant object are focussed behind the retina instead of on it, and this error of refraction may theoretically arise from three sources (Fig. 18).

FIG 18.—Hypermetropic Eye.



D. O. = Rays from distant object.
F. = Focus of such rays behind retina.
F_2. = Focus of such parallel rays, brought forwards by means of the exercise of accommodation.

(A) The hypermetropic eye may be too short in its antero-posterior diameter, *i. e.* from the cornea in front to the retina behind, so that the retina is moved too far forwards, and is too near to the refracting media of the eye.

(B) The refracting media of the eye may not be

sufficiently convex; thus becoming deficient in refractive power they are unable to focus on the retina the parallel rays of light from a distant object.

(c) Too low an index of refraction of the transparent media.

70. In all these cases the same thing will happen, viz. that the parallel rays of light from a distant object meet the retina before they have been sufficiently refracted to come to a focus, *i. e.* the principal focus of the eye is situated behind the retina (Fig. 18) and vision for distant objects is indistinct.

71. But if, *before* they meet the refractive media of the eye, the parallel rays from a distant object can be made to converge somewhat, then the hypermetropic eye, with its feeble refracting power (70), may be equal to focussing on the retina (instead of behind it) such already slightly converging rays.

In this case the hypermetropia is corrected by the lens, provided of course that its convexity is suited to the amount of the hypermetropia.

But though a hypermetropic eye ought *not* to have distinct vision for distant objects, yet we often find on testing a patient that his vision appears to be normal, *i. e.* that he can read the Test Type No. 6 Snellen at 6 metres, and yet he is the subject of hypermetropia.

How comes it then that this hypermetropic eye, in which vision for distant objects on theoretical grounds should be indistinct, appears to have normal distant vision?

The patient has been exercising his accommodation (Fig. 18).

In the emmetropic eye accommodation is used only for the purpose of focussing the diverging rays from a *near* object, but in this hypermetropic eye it has been used for focussing the parallel rays from a *distant* object.

72. In order to test this statement we place the patient at a distance of 6 metres from the test types, and we find his vision $= \frac{6}{6}$, *i. e.* is apparently normal for distant objects. We then place before his eyes say a $+ 0{\cdot}5$ D.

His vision, we will suppose, is still $\frac{6}{6}$.

We then continue to place before the eye + lenses of gradually increasing power, till we come to a lens with which the patient can no longer see $\frac{6}{6}$.

We then revert to the highest lens with which the vision was still $\frac{6}{6}$, and this lens is a measure of the *manifest* hypermetropia.

73. Supposing this lens to be a lens of $+ 2{\cdot}5$ D., then the patient has 2·5 dioptres of *manifest* hypermetropia or H. m., as it is usually written.

We have thus far learned that the eye under consideration is not an emmetropic eye which focusses on the retina parallel rays from a distant object. For if it were an emmetropic eye, these + lenses should have so increased the refraction of the rays that they would have been focussed in front of the retina—causing indistinct vision.

74. We will now paralyse the patient's accommodation by means of atropine, and on applying test lenses we find as the result of the paralysis of his accommodation that now he has distinct vision for distant

objects, even though say a + 4 D. lens is given him, *i. e.* his 2·5 D. of *manifest* hypermetropia are now increased to + 4 D. of *total* hypermetropia.

The paralysis of accommodation has disclosed 1·5 dioptres of hypermetropia which were previously not manifest.

75. Such hypermetropia is called *latent* hypermetropia, or H. l.

Hence the total hypermetropia of any eye always = H. m. + H. l. (manifest hypermetropia + latent hypermetropia = Total hypermetropia).

76. The latent hypermetropia is the result of a tonic spasm of the ciliary muscle, and arises in consequence of the accommodation of the eye being constantly used for the purpose of obtaining distinct vision for distant objects; hence the ciliary muscle is always in a state of tension.

77. Supposing that we consider an eye with a total hypermetropia of 6 dioptres, such an eye would require to exercise 6 D. of accommodation in order to focus on the retina the parallel rays from a distant object, *i. e.* it would only have distinct *distant* vision at the cost of the consumption of 6 D. of accommodation.

78. Now, accommodation is intended to be used for the purpose of giving distinct vision for *near* objects, and not for the purpose of distant vision.

79. How then will this irregular consumption of his accommodation affect this hypermetrope's near vision?

Clearly if 6 D. of accommodation are spent in

securing distant vision, his accommodation which is left for near objects is less by that amount which he has used for distant vision, *i. e.* in this case 6 D.

And supposing the hypermetrope to be thirty years of age, at which age there is usually only about 6 D. of accommodation, then this hypermetrope would have no accommodation at all remaining for near vision, and would simply have clear distant vision.

80. Hence the effect of hypermetropia on near vision depends not only on the amount of hypermetropia, but also upon the amount of accommodation which the patient has remaining according to his period of life.

81. But the amount of accommodation varies with age, for at

10 years	the accommodation	remaining	is	14 D.
20	„	„	„	10 D.
30	„	„	„	7 D.

It is clear, therefore, that if the hypermetropia be moderate in amount and the patient young, *i. e.* with a great amplitude of accommodation, then the hypermetropia will be of little inconvenience, as the patient by reason of his youth would be the possessor of such an amount of accommodation that he can afford to spend some in correcting his hypermetropia (*i. e.* for distant objects) and still have sufficient remaining to spend in securing distinct near vision.

Thus suppose we have + 3 D. of hypermetropia in a child ten years of age with 14 D. of accommodation. It is clear that he would have 11 D. of accommodation (14 D. — 3 D.) for near vision. So he would have enough accommodation and some to spare. For 11 D.

of accommodation would place his near point at 9 cm. ($\frac{100}{11}$=9 cm.).

But when he has arrived at thirty years of age his accommodation will naturally have decreased to 7 D. (**81**) and in this case, allowing + 3 D. for his hypermetropia, he can only have 4 D. of accommodation remaining, *i. e.* his near point will have receded to 25 cm.

In fact he will have become presbyopic at thirty years of age, since presbyopia is considered to commence when the near point has receded beyond a distance of 22 cm. from the eye.

82. But in making the calculations which we have done in the preceding paragraph (**81**) we have assumed that these hypermetropes have used *all* their accommodation, but it must be borne in mind that the habitual use by any eye of the whole of its possible accommodation may be attended with very evil consequences.

83. So that for the comfortable use of sustained accommodation at any distance, the eye must always have a portion of its accommodation unused, *i. e.* in reserve; such reserved accommodation is only to be used on special occasions and for short periods, and consequently if in the case cited (**81**) we allow for the accommodation which is required to be held in reserve, this boy of ten years of age with 3 D. of hypermetropia may have at his command, for sustained vision, only say 8 D. of accommodation instead of 11 D., and by the time that he is thirty years old there may be none at all remaining for near vision, after his 3 D. of hypermetropia has been provided for.

84. Therefore even in cases of hypermetropia of low degree the error had better be corrected, in order to avoid the consequences which may follow on the use of the whole of the accommodation which the eye is capable of exercising, and although in these cases nothing may occur to draw the patient's attention to any error in his sight, for so long as his accommodation continues vigorous it may suffice for giving him a distinct vision for both distant and near objects, yet when anything occurs to diminish the vigour of such accommodation, as ill-health or increasing years, with its natural failure of accommodation, then the balance of the patient's accommodation left over after the focussing of distant objects had been provided for, and which formerly sufficed also for focussing near objects, is now no longer sufficient for that purpose; and a person who up to the time of the occurrence of an illness had not noticed any failure of sight, is now often unable to see near objects distinctly.

The illness, by weakening the power of the over-acting ciliary muscle, has revealed the existence of the hypermetropia.

85. At first sight the correction of hypermetropia would seem to be comparatively easy, viz. to give the highest + lens which corrects the total hypermetropia, thus converting the eye into an emmetropic eye—with distinct distant vision, without any accommodation—and if a near object is required to be viewed, then by bringing the vigorous and hypertrophied ciliary muscle into play, the diverging rays

from the object would then be duly focussed on the retina by the aid of the resulting accommodation.

But in practice, except in cases of young persons with slight hypermetropia and vigorous accommodation, it is found best not to correct the whole of the total hypermetropia, but to order such lenses as will not correct quite all of it, and thus leave the eye to make a partial use of its accommodation.

86. The experience of ophthalmic surgeons prompts them to adopt somewhat varying rules, but the following will probably lead to satisfactory results :

(1) Ascertain the amount of manifest hypermetropia and add 1 D. as representing the latent hypermetropia ; or, better—

(2) Ascertain the amount both of manifest and latent hypermetropia, aud then we may follow the rule laid down by Donders.—

"That we should prescribe such glasses as correct the whole of the H. m. and one fourth of the H. l." (*Hartridge.*)

CHAPTER VI

PRESBYOPIA

87. Presbyopia is considered by many ophthalmic surgeons as commencing whenever the near point of distinct vision has receded beyond a distance of 22 cm. from the eye.

88. This being quite an arbitrary standard, a more scientific statement would be to say that presbyopia commences whenever the near point of distinct vision recedes beyond the most convenient working distance. And in this case it is evident that its commencement will vary according to the occupation as well as with the age of the patient. For correcting presbyopia on this basis see **106.** Inasmuch then as the arbitrary fixed standard for the commencement of presbyopia (22 cm.) has the merit of simplicity, and also renders a clear description of presbyopia more easy, we shall base our remarks on the supposition that presbyopia commences when the near point of vision has receded beyond 22 cm. from the eye, but we shall also give directions for its calculation and correction on the basis of its varying with the occupation and age of the patient (**96**).

In presbyopia, then, the near point recedes further and further from the eye in consequence of a gradual

decline in the power of accommodation—a decline which is the result of a decrease in the elasticity of the lens, accompanied probably by a diminution in the power of the ciliary muscle, and as accommodation mainly consists in an increase in the curvature of the lens, induced by the action of the ciliary muscle, it follows therefore that by reason of increase of age, not only is the lens, on account of its increasing firmness, less capable of responding to calls made on it to increase its curvature, but also that the ciliary muscle is less potent for calling such increased curvature into play.

Hence the power of accommodation must necessarily decrease with advancing years.

This gradual decline in the power of accommodation is supposed to commence at the age of ten years, at which age the eye possesses 14 D. of accommodation; at the age of twenty it has declined to 10 D., an amount of accommodation which would place the near point at 10 cm. from the eye, because $\frac{100}{10\text{ D.}} = 10$ cm.

At forty years of age the eye has only 4·5 D. of accommodation left, which would place the near point at 22 cm., because $\frac{100}{4{\cdot}5} = 22$ cm.

89. At forty years of age then the eye has arrived at the starting-point of presbyopia, as the power of its accommodation has declined to 4·5 D., and consequently the near point has receded to 22 cm. $\frac{100}{4{\cdot}5} = 22$ cm.

90. At about sixty-five years there is no power of accommodation at all remaining, and a patient of that age will require a + 4·5 D. lens in order to replace that loss of accommodation which has taken place since he was forty years old.

91. Thus in an emmetropic eye presbyopia may be said to consist in a gradual loss, between the ages of forty years and sixty-five years, of 4·5 D. of accommodation.

92. This disappearance of the 4·5 D. of accommodation has taken place at a regularly graduated pace, for 1 D. disappears with every five years added to the age of forty.

The oculist therefore has to dole out to his patient 1 D. of accommodation every five years, and he does this by placing *outside* the eye that amount of accommodation which has been lost, so to say, from the inside of the eye.

In fact, he supplies the missing accommodation in the shape of that + lens which will exactly equal the amount of the missing accommodation, every 1 D. lost being efficiently replaced by a + 1 D. lens.

93. At forty-five years there has been lost + 1 D. of accommodation, therefore a + 1 D. lens will be required outside the eye to replace the 1 D. which has been lost.

At fifty years there have been lost + 2 D. of accommodation, and therefore a + 2 D. lens will be required outside the eye to replace the + 2 D. which has been lost.

At fifty-five years there have been lost + 3 D., and

therefore a + 3 D. lens will be required to replace it.

At sixty years there have been lost + 4 D., and therefore a + 4 D. lens will be required to replace it.

At sixty-five years (about) all accommodation has disappeared, and therefore a + 4·5 D. lens will be required to replace it.

Such a patient at sixty-five years of age, having lost all accommodation, will have no point of near vision, though his distant vision may remain perfect.

94. Sometimes, however, distant vision becomes impaired by age chiefly in consequence of the lens becoming less convex, in which case the eyes may not be capable of focussing, as they used to do, the parallel rays from a distance; such rays would consequently be focussed behind the retina as in hypermetropia, and the patient is then said to have a species of hypermetropia which is known as *acquired* hypermetropia.

95. In all the instances given in (**93**) it will be seen that in an ordinary case of presbyopia a simple subtraction sum has to be done if we wish to supply the proper correcting lens.

(A) Find out that lens whose focal distance is the required near point, *e. g.* if the required near point of vision is 22 cm., then the lens required is + 4·5 D. $\left(\frac{100}{22} = 4{\cdot}5 \text{ D.}\right)$.

(B) From that lens subtract the amount of accommodation which remains for the age of the patient under consideration.

Say the age is fifty-five years. At that age the accommodation remaining is + 1·5 D., for, since the age of forty, when he had remaining 4·5 D. of accommodation, he has passed through three spaces of five years each, and during each space he has lost + 1 D. of accommodation. Hence his total loss is + 3 D., and if 3 D. be subtracted from 4·5 D., he therefore has remaining 1·5 D. of accommodation, or, to put it in figures,—

Lens representing required near point . .	4·5
Accommodation lost since forty years . .	3
Accommodation remaining at fifty-five years	+ 1·5 D.

(C) Then having found the accommodation remaining, subtract (B) from (A).

Thus at fifty-five years

Required near point (A)	4·5
Accommodation remaining at fifty-five years (B)	1·5
Lens required	+ 3 D.

96. It must be remembered, however, that for special occupations the near point may be required to be at some other distance than 22 cm., and then the terms of the sum will have to be varied accordingly.

Suppose the near point is required to be at 40 cm. instead of 22 cm.

Then $\frac{100}{40} = 2{\cdot}5$ D.

Therefore with a patient of fifty-five years our sum will be varied as follows :

Lens representing required near point . .	2·5 D.
Accommodation remaining at fifty-five years	1·5
Lens required	+1 D.

But in all cases it is in practice found best to give a lens a little below the fully correcting power as found by the above method.

To repeat—an emmetropic eye is one which in a state of rest (*i. e.* exercising no accommodation) has distinct vision for the parallel rays from distant objects, but such an eye, by bringing into play its power of accommodation, is able also to have distinct vision for the diverging rays from a near object.

Hence such an eye has a distant point of distinct vision and also a near point of distinct vision.

But as age advances there is a gradual diminution in the extent of this accommodating power of the eye, the result of which is that as years go by the near point of distinct vision recedes further and further from the eye in proportion to the decrease of the power of accommodation, and the same type which at a distance of 22 cm. could be read distinctly by a person of forty years of age, would, when the reader is fifty years old, have to be held at a distance of 40 cm., in order to be seen as clearly as it was seen ten years previously. Such a condition of things is called presbyopia.

Of course if the size of the type is gradually increased according to the gradual disappearance of the accommodation, it could still be read at 22 cm. And this is what most presbyopics do.

In order to delay taking to the use of spectacles, they take to using large print, rejecting the smaller type, till it becomes rather difficult to supply them with the type which they like, and then they are driven as it were to spectacles, which practically make their small type into large type.

The explanation of this necessity for moving the type further and further from the eye as age advances, is that the further the type is from the eye the less divergent are the rays proceeding from it to the eye, and since they are less divergent, less accommodation of the eye is called for in order to focus such rays on the retina.

This is just what such an eye requires in advancing years, because it possesses less and less power of accommodation.

Thus presbyopic persons meet their loss of the power of accommodation by making less demand on that power, or, in other words, by moving the type further off, they supply to the eye rays of just such an amount of divergence as they know by experience that their eye can focus on the retina.

97. Inasmuch as in presbyopia the near point gradually recedes by time-regulated stages it follows that if the rate of decrease of accommodation is known, as well as the patient's age, we can also know what is the amount of his presbyopia (assuming of course that it commences at 22 cm.) or if his presbyopia is known, his age can be approximately fixed.

98. But the above statements only apply of course to the emmetropic eye, for it is clear that presbyopia

will be considerably modified both as to the time of its commencement and the rate of its progress, according as the eye was originally myopic or hypermetropic.

99. In hypermetropia, for instance, suppose there is + 2 D. of hypermetropia.

That will clearly mean that + 2 D. of accommodation has been consumed by the eye, in order to focus *distant* objects.

It follows then that during all the time which the hypermetropia has existed, the eye has had + 2 D. less of accommodation for *near* objects than has an emmetropic eye of the same age—or in other words, the accommodation for near objects is less *by* the amount which has been expended on distant objects, viz. + 2 D.

And if the emmetropic eye at the age of forty years has + 4·5 D. of accommodation remaining, and therefore placing its near point at 22 cm. $\left(\frac{100}{4{\cdot}5\text{ D.}} = 22\text{ cm.}\right)$; it follows that at the same age the eye with + 2 D. of hypermetropia will only have 2·5 D. of accommodation *remaining* for near objects, instead of the 4·5 D. which it ought to have, because, although its total amount of accommodation is not less than in an emmetropic eye of the same age, it has applied its accommodation differently, part having been applied to distant objects, whereas the whole of it ought to have been expended on focussing near objects.

Consequently at forty years of age this eye with + 2 D. of hypermetropia has only 2·5 D. of accommodation remaining which it can apply to a near

object, and its near point will therefore be at 40 cm. $\left(\frac{100 \text{ cm.}}{2{\cdot}5 \text{ D.}} = 40 \text{ cm.}\right)$, whereas an emmetropic eye of the same age, with its 4·5 D. of accommodation, would have its near point at 22 cm. $\left(\frac{100 \text{ cm.}}{4{\cdot}5 \text{ D.}} = 22 \text{ cm.}\right)$.

So that if presbyopia is considered as commencing when the near point is beyond 22 cm., then this patient with + 2 D. of hypermetropia has really been presbyopic for some time previously to attaining forty years of age, whereas at forty years the emmetropic eye is only just beginning to assume presbyopia.

100. Hence we find that in hypermetropic eyes presbyopia *must* commence at a much earlier age than it does in emmetropic eyes.

101. Therefore, in making our calculations for presbyopia occurring in a hypermetropic eye, it is evident that we must make due allowance for the hypermetropia, and this can be done (1) by correcting the hypermetropia, *i. e.* by converting the hypermetrope into an emmetrope; and then (2) by treating his presbyopia as we should treat it (**95**) if there was no hypermetropia existing, which is equivalent to saying we must *add* to the lens which represents the hypermetropia that lens which would suit an emmetrope with presbyopia.

Thus in the case we have considered of hypermetropia + 2 D. in a patient fifty-five years the lens required would be + 5 D. instead of + 3 D. which would be required if his eye were emmetropic. The calculation would be:

Lens representing near point required .	4·5 D.
Accommodation remaining at fifty-five years	1·5
Lens required for an emmetrope	+3 D.
Add on + 2 D. hypermetropia	2 D.
Lens required allowing for the + 2 D. of hypermetropia	+5 D.

102. In the myopic eye everything is the reverse, so to say, of the hypermetropic eye. Suppose we have to deal with a case of − 4·5 D. of myopia.

That means that the patient's *far* point of distinct vision is 22 cm. $\left(\frac{100}{4{\cdot}5\text{ D.}} = 22\text{ cm.}\right)$. Therefore he requires to exercise no accommodation in order to see at 22 cm.

Hence the total loss of his accommodation can never make any difference to him, for he will always be able to see distinctly at 22 cm., which is his *far* point, therefore he can never become presbyopic.

Of course if the myopia is of a higher degree than − 4·5 D. it is still more impossible for him ever to become presbyopic.

A patient therefore with − 4·5 D. or more of myopia can never become presbyopic, and in cases of myopia of less than − 4·5 D. the date of the commencement of presbyopia is necessarily postponed—in comparison with the date of its commencement in emmetropes.

For just as myopia is the reverse of hypermetropia, and as the hypermetrope, when wishing to use his

accommodation for near vision, starts at a disadvantage in comparison with an emmetrope, because his far point from which he starts is *beyond* infinity, *i. e.* six metres; so, on the contrary, the myope, in comparison with an emmetrope, starts for the near point with an advantage, because the *far* point from which he starts is nearer than infinity—how much nearer will depend on the amount of his myopia.

103. As the *disadvantage* of the hypermetrope, in connection with presbyopia, is measured by the amount of his hypermetropia, so the *advantage* of the myope is also measured by the amount of his myopia.

A myopic eye, therefore, before it could be the subject of presbyopia, must lose, in the run for the near point, all the advantage which its myopia gave it, and as this advantage is measured by the amount of the myopia, it follows that in remedying presbyopia in a myopic eye we must do exactly the reverse of what we did in hypermetropia.

In the hypermetropic patient, by first correcting his hypermetropia, before proceeding to deal with his presbyopia, we virtually deprived him of the *disadvantage,* in connection with the near point, which his hypermetropia gave him, his far point having been *beyond* infinity, of course.

Similarly, in a case of presbyopia occurring in a myope, we proceed to deprive him of the *advantage* in connection with the near point which his myopia gives him; that is, we first correct his myopia and then treat his presbyopia as we should do if he was an emmetrope.

This is equivalent to saying that we must *subtract* that lens which represents his myopia from the lens which would suit an emmetrope of the same age.

Therefore, in a case of myopia − 2 D. in a person aged fifty-five years, we should work as follows:

Near point required	4·5 D.
Accommodation remaining at fifty-five years	1·5
Lens required if there was no myopia .	+3 D.
Subtract the amount of myopia	−2 D.
Lens required	+1 D.

or, which amounts to the same thing, correct the myopia by − 2 D. lens; then correct the presbyopia + 3 D., and + 3 D. − 2 D. = + 1 D.

104. It follows, from what has been said above, that as the hypermetrope has a disadvantage and the myope an advantage in connection with presbyopia, so in hypermetropia we have presbyopia commencing early, and in myopia its advent is delayed, the variation in each case depending on the amount of the error of the refraction.

Hence the origin of the popular idea that short-sighted persons are also strong sighted, by which is meant that they are longer in showing the result of the failure of their accommodation.

105. Table of amount of presbyopia in an emmetropic eye:

Age.		Distance of near vision.		Lens required to bring near points to 22 cm.
		cm		
40	...	22	...	+ 0
45	...	28	...	+ 1 D.
50	...	43	...	+ 2 D.
55	...	67	...	+ 3 D.
60	...	200	...	+ 4 D.
65	...	Infinity	...	+ 4·5 D.

106. If we prefer to regard presbyopia, not as commencing when the near point has receded beyond a given fixed unvarying distance, but as presenting itself whenever the near point has receded to an inconvenient distance, and this, as said before, is a more scientific view to take of it, then the method for its correction will vary somewhat from that previously described.

The first thing to do is to find out at what distance from the eye the near point is in any given case.

The near point, or punctum proximum, is that point at which Snellen's No. 5 Type and Jaeger's No. 1 Type can be clearly read. We will suppose then that the near point is at a distance of 50 cm. from the eye, and that the patient requires to be able to read at a distance of 25 cm.

Now, it is clear that what we have to do is to bring the near point from 50 cm. distant to a point 25 cm. distant.

It is equally clear that to bring the near point from infinity to 50 cm. involved the exercise of 2 D. of accommodation, because $\frac{100}{50} = 2$ D.

It is equally clear that to bring the near point from infinity to 25 cm. would involve the exercise of 4 D. of accommodation, because $\frac{100}{25} = 4$ D.

Therefore if we increase the accommodation by the amount which it fell short of in its effort to bring the near point to 25 cm., we shall have accomplished the desired end, and shall have remedied the presbyopia.

Hence the difference between the patient's actual near point and his desired near point will measure the deficiency of his accommodation, and therefore in the above case as

25 cm. = 4 D. of accommodation, and
50 cm. = 2 D. of accommodation,

therefore + 2 D. of accommodation is the difference between the actual near point and the one desired, and a + 2 D. lens would bring the near point to 25 cm.

It is evident that there is a much greater amount of elasticity about this system of correcting presbyopia as compared with its fixed definition as commencing at 22 cm., since it is capable of being varied to suit every kind of requirement.

For the difierence between the two points being found, that difference accurately represents the accommodation which has been lost, and which it is required to replace.

Any existing hypermetropia or myopia must of course be corrected previously to finding out the near point, and will have to be allowed for when calculating

the lens required, just as was done under the fixed 22 cm. method, viz. by adding the lens which corrects the hypermetropia and subtracting that which represents the myopia.

CHAPTER VII

ACUTENESS OF VISION

107. In order to compare the vision of one person with that of another, or to be able to note the exact amount of improved vision which any patient receives at our hands, it is necessary that we should have a generally accepted standard of vision. Such a standard would then be regarded as the standard of normal vision.

108. The standard, then, of normal vision which is generally accepted is that a normal eye should see clearly any object which subtends an angle of 5 minutes, *i. e.* which subtends the visual angle.

And, taken in connection with the test types generally used, what is meant by a statement that the object to be seen by the normal eye must subtend an angle of 5 minutes?

109. Before answering this question we must understand what the visual angle means:

It is well known that the retina receives on its surface an impression of an inverted image of any object which is focussed on it, *i. e.* the axial rays from an object cross and are refracted by the surface of the cornea, the front surface of the lens, and the front

surface of the vitreous, so that they cross one another at the point N, Fig. 19, which is called the nodal point, and then form the inverted image on the retina.

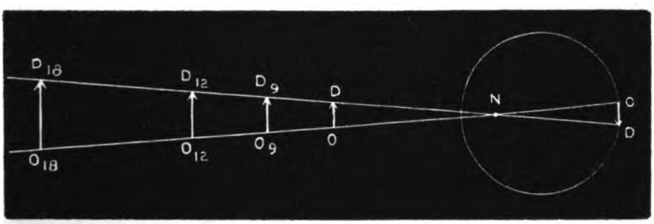
The angle at N is called the visual angle and is an angle of 5 minutes.

It is evident that if D O, Fig. 19, be an object situated at a distance of 6 metres from the nodal point N of the eye, which is emmetropic, it would form an impression O D on the retina. And if the angle at N is an angle of 5 minutes, then an object of the size of D O subtends an angle of 5 minutes, and if it be removed still further off to

D_9 O_9 at a distance of 9 metres, or to
D_{12} O_{12} ,, ,, 12 metres, or to
D_{18} O_{18} ,, ,, 18 metres,

and at the same time were to become increased in size (as in Fig. 19) in proportion to its increased

FIG. 19.



distance from N, it will in each case still continue to subtend an angle of 5 minutes.

110. Hence, if D O were a letter in the test type and of such a size as would subtend an angle of 5 minutes at N, it will be focussed on the retina with distinct

vision if the eye is emmetropic, and would be known as No. 6 type, and we should state that the vision was normal by the formula that

$$V. = \frac{6 \text{ metres}}{6 \text{ type}} = 1.$$

(or distance at which the type is read divided by the number of the type)

Or, in the same way, we should say of a smaller letter that vision was normal because

$$V. = \frac{5 \text{ metres}}{5 \text{ type.}} = 1.$$

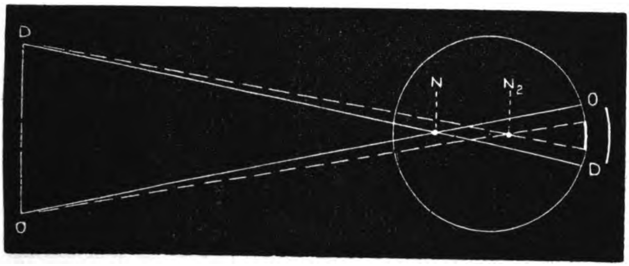
And so on for still smaller letters at decreasing distances. But it is not safe to rely upon this test at less than 3 metres distance, because the accommodation of the eye may be brought into play in reading the types at shorter distances.

The test types usually employed are Snellen's. They of course should be exposed to a good light when we are testing acuteness of vision, and in anything like a prolonged period of testing we ought to have a duplicate set of letters on the reverse side of the board, as patients are often very quick at learning their letters.

111. It will be evident then that in any given eye the exact position of the nodal point N is of great importance as regards the refraction power of that eye; and that if from any circumstances the position of the nodal point should be shifted either nearer to or further from the cornea, that very great consequences will result from such a shifting. We will only take notice of the following.

112. In Fig. 20 let N represent the nodal point in a myopic eye, a point placed nearer to the cornea than

FIG. 20.



N. = Nodal point in myopic eye.
N_2. = Nodal point in hypermetropic eye. The nodal point in an emmetropic eye would be situated somewhere between N and N_2.

it is in an emmetropic eye, and let N_2 be the nodal point of a hypermetropic eye, placed further away from the cornea than it is in an emmetropic eye.

It is clear that the angle at N in the myopic eye will be a larger angle than is the angle at N_2 in the hypermetropic eye.

113. Hence in the myopic eye, with its anterior nodal point, the object D O will form a larger image O D on the retina than it does in the case of the hypermetropic eye with its posterior nodal point. (The image of the hypermetropic eye is represented by the dotted line.)

In an emmetropic eye the nodal point would be situated somewhere between the points N and N_2, and hence its image on the retina would be intermediate

in size between that of the myopic and hypermetropic eye.

114. Hence the correctness of the statement that myopic eyes have larger impressions of a given object than the emmetropic or hypermetropic eye has; and this is shown practically, for it is a matter of frequent observation that a short-sighted person is what is popularly called a strong-sighted person, that is to say, if we start an emmetrope and a myope to look for a small object dropped on the carpet, the chances are that the myope will find it first, because the larger image of the object which he receives on his retina gives him an advantage.

115. It is well known that biconvex lenses enlarge and biconcave lenses diminish the images received on the retina. This somewhat follows from what we have written as regards the size of the images in hypermetropia and myopia (**113**) (**114**).

It will be seen clearly, therefore, if the nodal point is by any means brought forwards (compared with the position of it in the emmetropic eye), it necessarily follows that we have placed the nodal point in the same forward position which it occupies in myopia, and hence that the visual angle at N will have been made larger, and therefore (**112**) that the image on the retina has become enlarged.

A convex lens, by giving convergence to the rays before they meet the cornea, will of necessity bring forward the nodal point and so give us an enlarged image on our retina.

Hence the + lens has magnified the image for us.

116. It follows, therefore, that a concave lens does the reverse of a convex lens, and therefore a — lens in front of the eye will displace the nodal point further back from the cornea and thus *diminish* the visual angle N.

Hence, the image received on the retina will be diminished in size.

117. This fact of the smallness of the image which we receive when looking through — lenses explains one of the reasons why, when fitting myopic patients with — lenses, we do not always give them the fully correcting lens.

Such a lens would often so diminish the size of the letters of a book that the patient, in order to enlarge the size of the image on his retina, will perhaps bring the book close up to his eyes. Thus, a too powerful — lens will, in this case, have created over again the very mischief for the correction of which it was originally supplied.

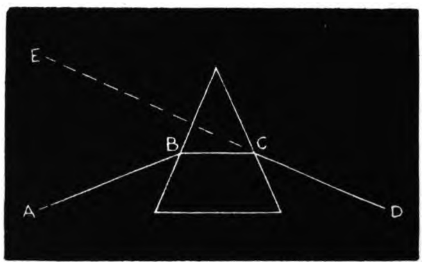
CHAPTER VIII

PRISMS AND CYLINDRICAL LENSES

118. Rays of light when passed through a prism are refracted towards the thickest part of the prism.

Thus in Fig. 21 a ray of light A B meeting the sur-

FIG. 21.

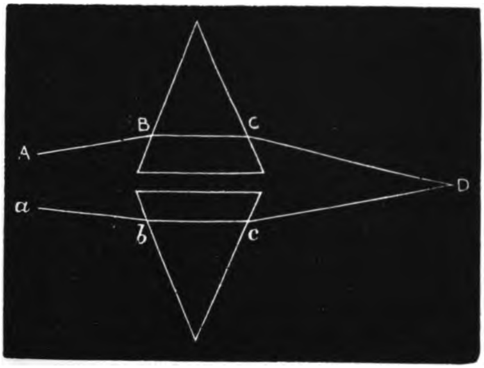


face of the prism at B will then be refracted to the position of B C, and at C again it will be refracted in the direction of C D, and though the ray proceeded from A, yet an observer at D would refer such a ray to the point E, *i.e.* to a point representing D C prolonged.

119. If we place two prisms together so that their bases are adjacent we practically manufacture a con-

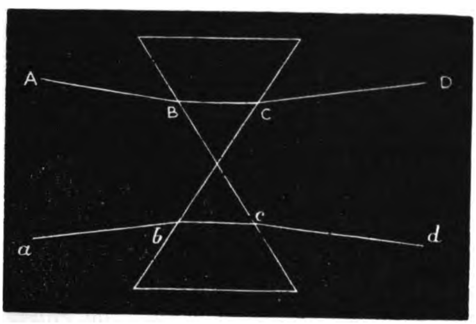
vex lens as in Fig. 22, when the rays from A a will be focussed at D.

FIG. 22.



120. Similarly if we reverse the position of the prisms, placing their bases upwards so that their apices

FIG. 23.



are adjacent, Fig. 23, we practically manufacture a concave lens; for as each prism refracts the rays

towards its base, *i.e.* towards the thickest part, the two when placed with their apices adjacent will cause the rays of light to diverge as if they had passed through a concave lens.

We have thus far considered + and — spherical lenses; and for the purposes of this book we need only to take cognisance of three kinds, viz.:

(1) + spheres or biconvex lenses, *i. e.* with both surfaces convex.

(2) — spheres or biconcave lenses, *i. e.* with both surfaces concave.

(3) Cylindrical lenses, convex and concave.

If we hold a spherical biconvex lens vertically in front of our eye, and at the level of it, we may consider the lens as having (1) an upper or north point;

FIG. 24.

Biconvex or + lens.

FIG. 25.

Biconcave or — lens.

(2) a lower or south point; (3) an east point; and (4) a west point; and if we move our finger vertically from north to south over its distant surface we note that this vertical meridian is curved or convex; and if we move our finger from east to west horizontally over the same surface we find that its horizontal

meridian is also curved or convex. And however much we rotate the lens in our fingers we always have a north and south convex vertical meridian, and also an east and west convex horizontal meridian.

These two meridians, called respectively the vertical and horizontal meridians, are thus at right angles to each other and present exactly equal amounts of curvature.

If we regard this lens as representing the convex cornea then we may consider the cornea also as having vertical and horizontal meridians, each convex to the same extent.

121. If in the cornea these two meridians are not *equally* curved, then we have that error of refraction which is called astigmatism, see (**127, 128, 129**).

What has been said above (**120**) in relation to a convex lens applies equally to a concave lens.

122. A cylindrical lens differs from a spherical lens in the fact that it has only *one* of its meridians curved.

Cylindrical lenses are spoken of as having an axis, the meaning of which will be explained further on.

In order to form an idea of a cylindrical lens we will take a round cedar pencil, then split it in halves where the halves are glued together; we will then cut off from one half of the pencil a piece one inch in length.

If we hold this piece of pencil one inch long in front of our eyes so that the glued flat surface is towards the face, and the curved surface turned away from the face, and if we hold it with the long axis (one inch) vertically, then the curved surface may be

considered as having a north and south vertical meridian one inch in length, and also an east and west horizontal meridian equal to half the circumference of the original pencil.

But only one of the meridians of this piece of pencil (or cylindrical + lens as it really is in shape) is curved.

Which of the two meridians will be the curved one will entirely depend on the direction of the axis (one inch long) of the pencil or cylindrical lens.

(A) For if, when the long axis is held vertically with the glued surface towards our face, we pass our finger over the distant surface from north to south, or over the vertical meridian, we shall pass it over a plane surface; and hence the vertical meridian (corresponding with the direction of the axis of the lens) is plane, not convex.

(B) But if we now pass the finger over the distant surface from east to west, that is over the horizontal meridian, we shall have passed it over a convex surface, corresponding to half the circumference of the original whole pencil.

123. Thus with the axis of this cylindrical + lens held *vertically*—

(A) The *vertical* meridian is plane *non*-refracting.

(B) The horizontal meridian is convex and refracting.

Suppose now we hold the long axis of the lens *horizontally*, then—

(A) The *horizontal* meridian is plane *non*-refracting.

(B) The vertical meridian is now the convex and refracting one.

124. Hence this cylindrical lens can be made to fulfil two different purposes according as the axis is placed vertically or horizontally; and the point to remember is that, whichever way it is placed, the direction of the axis represents the direction of the plane non-refracting meridian; and consequently, the meridian which is at right angles to the direction of the axis always represents the refracting meridian.

Hence the necessity for some mark on cylindrical lenses whereby we may know the direction of their axes. In many boxes of trial lenses the axis or direction of the non-refracting meridian is indicated by the direction of a strip of ground glass on the margin of the lens.

The use of cylindrical lenses is to correct errors in the refraction of *one* of the meridians of the cornea in astigmatism.

125. For instance, one form of astigmatism, simple hypermetropic astigmatism, presents a cornea with a vertical meridian of *normal* refraction, and therefore the refraction of that vertical meridian does not require to be interfered with.

But the horizontal meridian of such an eye may be hypermetropic say to the extent of 2 D., and this horizontal meridian requires a +2 D. lens to bring back on to the retina the focus of the horizontal meridian, and at the same time we must not interfere with the vertical meridian, which is normal.

The remedy for this state of things will be clearly

a +2 D. *cylindrical* lens, placed with its axis (*i. e.* its non-refracting meridian) vertical.

With the cylindrical lens in that position the vertical meridian of the cornea is unaltered, whilst the horizontal meridian is supplied with increased refracting power to the extent of +2 D.

Had we used a +2 D. *spherical* lens we should have altered the refraction of both vertical and horizontal meridians of the cornea and have done no good; because at the same time that the sphere was correcting the faulty horizontal meridian of the cornea, it would necessarily create an error in that vertical meridian of the cornea which had previously been an emmetropic meridian; and thus we should have changed a faulty horizontal meridian into a faulty vertical one.

All the above remarks touching cylindrical plus lenses of course apply equally to cylindrical minus lenses; and the main point to remember is:

(1) If the axis is vertical, the horizontal meridian is refracting.

(2) If the axis is horizontal, the vertical meridian is refracting.

126. Cylindrical lenses are numbered in the same way as spherical lenses, according to the refracting power of their one refracting meridian.

Thus cylindrical lenses of +1 D., +2 D., +3 D., &c., or −1 D., −2 D., −3 D., &c., would mean that the one refracting meridian which they possess, whether it was convex or concave, is of the power of a spherical lens of 1, 2, 3, &c., dioptres.

CHAPTER IX

ASTIGMATISM

127. When we say that an eye is the subject of astigmatism we mean that the vertical and the horizontal meridians of that eye refract unequally.

This error of refraction may exist:

(A) In one meridian only.

(B) In both meridians.

128. When only one meridian has faulty refraction, the other meridian being emmetropic, we then have a case of simple astigmatism.

129. When both meridians have faulty refraction we then have either:

(A) Compound astigmatism or

(B) Mixed astigmatism.

130. It will help us towards gathering a good idea of the different forms of astigmatism if we take it as a fact:

(A) That the vertical meridian of the cornea is naturally more convex than is the horizontal meridian, and therefore:

(B) In all the forms of astigmatism the focus of those rays which are refracted by the vertical meridian

is always more anterior (*i. e.* nearer to the cornea) than is the focus of those rays which are refracted by the horizontal meridian (*vide* **131**).

Let us cut in halves lengthwise an ordinary shaped pear, *i. e.* one whose length is greater than its breadth. Then let us hold one half in front of our eyes, with the long axis horizontal : the cut flat surface towards us, and the round surface turned away from us.

Then we may think of the round surface of the pear as giving us roughly the shape of the meridians of the cornea.

For if we pass one finger downwards over the round front surface of the pear (*i. e.* from north to south as it were) we shall pass it over the vertical and *more* convex meridian of the pear (or cornea); and if we pass the finger horizontally from one end of the pear to the other (*i. e.* from east to west as it were) we shall pass it over the horizontal and *less* convex meridian of the pear (or cornea).

This increased convexity of the vertical meridian will help us to understand why in most of the various kinds of astigmatism the focus of those rays which are refracted by the vertical meridian is nearer to the cornea than is the focus of those rays which are refracted by the horizontal meridian.

131. It is not absolutely correct to say that in *all* cases of astigmatism the vertical rays are focussed in front of the point at which the horizontal rays come to a focus, for the reverse of this is sometimes the case, but by accepting the statement that the vertical meridian is the most convex and therefore has its

focus, more anterior than is the focus of the horizontal meridian, we are able more easily to get a fixed idea of the varying errors in the several kinds of astigmatism.

So that while we remember the comparison of the curves of the meridians of the pear when lying, as it usually does, on its side, thus presenting a more convex vertical meridian, yet we must also remember that a pear *can* be placed so as to rest upon its end, in which position its vertical meridian will no longer be the most convex.

In applying this to astigmatism we argue that just as a pear *usually* lies on its side with its vertical meridian most convex, so in cases of astigmatism do we usually find that the vertical meridian of the cornea is the most convex, and therefore has its focus anterior to the focus of the horizontal meridian; but that, inasmuch as a pear *can* stand on its end, and in this position would have its horizontal meridian most convex, so also an astigmatic eye may also have its horizontal meridian most convex, with the necessary result that in this case the focus of the horizontal rays would be anterior to the focus of the vertical rays.

132. There are then five varieties of astigmatism:

(1) Simple myopic astigmatism.

(2) Simple hypermetropic astigmatism.

(3) Compound myopic astigmatism.

(4) Compound hypermetropic astigmatism.

(5) Mixed astigmatism.

133. In simple astigmatism, whether simple myopic

or simple hypermetropic, only one meridian has an error of its refraction.

134. In compound astigmatism, whether compound myopic or compound hypermetropic, both meridians have errors:

(A) Either both are myopic, but in different degrees, then we have compound myopic astigmatism.

(B) Both being hypermetropic, but in different degrees, then we have compound hypermetropic astigmatism.

135. In mixed astigmatism both meridians have errors of refraction, one meridian being myopic and the other being hypermetropic.

We will at present discuss only the simple forms of astigmatism; and we will assume that for their diagnosis and treatment we only use the usual trial lenses with the astigmatic clock and the usual test types; ignoring the valuable assistance of the ophthalmoscope.

Simple Myopic Astigmatism.

136. This being simple, as we have only one meridian in error (**133**), the other meridian being emmetropic. And the name of simple myopic astigmatism would lead us to suppose that the faulty meridian was erring in the direction of myopia.

This is just the case.

Therefore in simple myopic astigmatism we have one meridian myopic and the other meridian emmetropic.

Which meridian then do we expect would err in the direction of myopia?

Clearly the vertical meridian, because:

(A) Myopia is always associated with the idea of too much convexity of the refracting media.

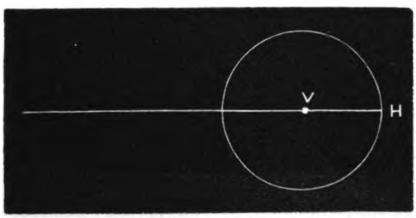
(B) The vertical meridian, being naturally more convex than the horizontal, is that meridian which we should expect would assume a condition of too great convexity.

Hence, in simple myopic astigmatism we find:

(1) The vertical meridian myopic.

(2) The horizontal meridian emmetropic (Fig. 26).

FIG. 26.—SIMPLE MYOPIC ASTIGMATISM.



V. = Myopic focus of vertical meridian.
H. = Emmetropic focus of horizontal meridian.

Simple Hypermetropic Astigmatism.

137. This also being simple astigmatism we have again one meridian in error, the other being emmetropic.

And its name would lead us to suppose that the faulty meridian was erring in the direction of hypermetropia.

This is the case.

So in simple hypermetropic astigmatism one meridian is hypermetropic, the other is emmetropic.

Which meridian then do we expect would err in the direction of hypermetropia ?

Clearly the horizontal meridian, because :

(A) Hypermetropia is associated with the idea of *too little* convexity of the refracting media.

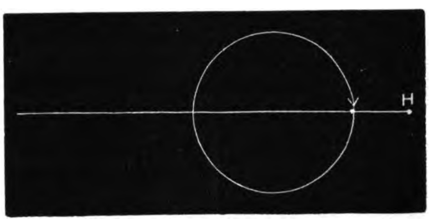
(B) The horizontal meridian, being naturally less convex than the vertical meridian, is that meridian which we should expect *would* assume a condition of too little convexity.

Hence, in simple hypermetropic astigmatism we find :

(1) The vertical meridian is emmetropic.

(2) The horizontal meridian is hypermetropic (Fig. 27).

Fig. 27.—Simple Hypermetropic Astigmatism.



V. = Emmetropic focus of vertical meridian.
H. = Hypermetropic focus of horizontal meridian.

138. Here it may be as well to mention that although we talk of the two faulty meridians of the cornea as being the vertical and horizontal meridians,

yet we must remember that they are seldom situated exactly according to their names. But the point to remember in connection with them is that, however they may deviate respectively from the direction which their name would imply, yet they are always at right angles to each other in all cases of astigmatism.

How the exact directions of the meridians can be arrived at will be explained further on.

CHAPTER X

COMPOUND ASTIGMATISM

We have said before (**134**) that there are two kinds of compound astigmatism :

(1) Compound myopic astigmatism.

(2) Compound hypermetropic astigmatism.

And also (**134**) that in all cases of compound astigmatism both meridians are faulty in their refraction. We will first consider:

Compound Myopic Astigmatism.

139. This being compound astigmatism, both meridians are in error; and its name, compound *myopic* astigmatism, might lead us to suppose that both the faulty meridians erred in the direction of myopia.

This is just what they do in compound myopic astigmatism, for in this error of refraction both meridians are myopic.

But these myopic meridians must be myopic in different degrees; for if both were myopic to the *same* extent we should have myopia pure and simple without any astigmatism.

Therefore, in compound myopic astigmatism one meridian must be more myopic than the other.

Hence it is a kind of irregular myopia, but differing from it by the fact that one meridian is more myopic than the other.

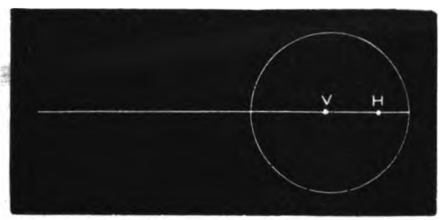
And which of the two meridians should we expect to be the most myopic?

Clearly the vertical meridian.

Because, since the term myopia always conveys an idea of too great convexity, and since the vertical is naturally more convex than the horizontal meridian, the vertical starts in front of its fellow meridian (horizontal) in the race for the joint development of the myopic astigmatism.

It is only reasonable, therefore, to expect, when both meridians have arrived at the condition of myopia, that the most myopic meridian would be that one

FIG. 28.—COMPOUND MYOPIC ASTIGMATISM.



V. = Myopic focus of vertical meridian.
H. = Myopic focus of horizontal meridian.

which, by reason of its greater comparative convexity, started with a tendency to myopia.

140. Therefore, in compound myopic astigmatism

we have both meridians myopic, and of the two the vertical is the most myopic.

Compound Hypermetropic Astigmatism.

141. This being compound astigmatism, both meridians are in error, and its name, compound hypermetropic astigmatism, might lead us to suppose that both the faulty meridians erred in the direction of hypermetropia.

This is just what they do in compound hypermetropic astigmatism, for in this error of refraction both meridians are hypermetropic.

And just as in compound myopic astigmatism both meridians are myopic, so in this compound hypermetropic astigmatism both meridians are hypermetropic, but in different degrees, or else we should have pure and simple hypermetropia without any astigmatism.

142. Therefore, in compound hypermetropic astigmatism, one meridian is more hypermetropic than the other, and hence, just as compound myopic astigmatism was said to be an irregular form of myopia (**139**), so compound hypermetropic astigmatism may be considered as an irregular form of hypermetropia, but differing from pure hypermetropia by the fact that one meridian is more hypermetropic than the other.

And which of the two meridians should we expect to be the most hypermetropic?

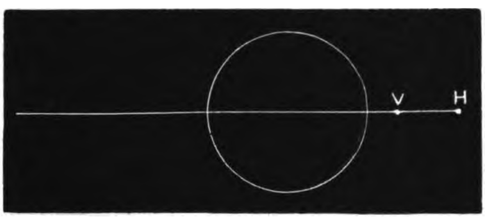
The horizontal meridian, of course; because since the term hypermetropia always conveys an idea of

deficiency in refractive power, that is an idea of flatness of the refracting media, and since the horizontal is naturally flatter than the vertical meridian, it follows that the horizontal meridian has the start, so to say, over its fellow meridian in the race for the joint development of the hypermetropia which they are both afflicted with in this compound hypermetropic astigmatism.

It is only reasonable, therefore, to expect, when both meridians have arrived at the condition of hypermetropia, that the *most* hypermetropic meridian should be that meridian which, by reason of its greater comparative flatness, started with a tendency to hypermetropia.

143. Therefore, in compound hypermetropic astig-

FIG. 29.—COMPOUND HYPERMETROPIC ASTIGMATISM.



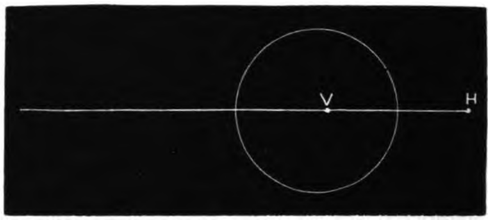
V. = Hypermetropic focus of vertical meridian.
H. = Hypermetropic focus of horizontal meridian.

matism we have both meridians hypermetropic, and of the two the horizontal is the most hypermetropic.

144. In mixed astigmatism we have both meridians at fault in their refraction, but each in a different direction, for the vertical, naturally curved meridian has

become more curved, *i. e.* more myopic; and the horizontal, naturally flat meridian has become more flat, *i. e.* more hypermetropic, as explained by Fig. 30.

FIG. 30.—MIXED ASTIGMATISM.



V. = Myopic focus of vertical meridian.
H. = Hypermetropic focus of horizontal meridian.

CHAPTER XI

SIMPLE MYOPIC ASTIGMATISM

THE diagnosis and treatment of simple astigmatism, whether myopic or hypermetropic, is easy when once our suspicion of the existence of astigmatism has been aroused.

145. We are led to suspect the presence of astigmatism when (supposing that there is no evidence of organic deep-seated mischief in the eye) we are unable, by any trial lenses, to effect anything more than a trivial improvement of distant vision; or when, as sometimes happens, a + lens seems to improve the distant vision almost as much as a − lens.

146. Suspecting then the presence of astigmatism, we place the patient at a distance of 6 metres from the ordinary distant test type and at the same distance from the astigmatic clock, and the direction of the most distinct lines on the clock face will point out the direction of the most erroneous meridian, and consequently the meridian which is at right angles to the most erroneous one will be the *least* erroneous meridian.

With the test type we find, say:

V. $= \frac{6}{18}$.

With the clock we find:

Vertical lines (from 12 o'clock to 6 o'clock) distinct.

Horizontal lines indistinct.

From this we learn :

(1) That the vertical meridian is ametropic.

(2) That the horizontal meridian is emmetropic; or, at all events, that the vertical meridian which shows the most distinct lines deviates more from emmetropia than does the horizontal.

We now fix in the trial frame a stenopaic slit, which is a wooden or metallic disc with an oblong slit in it of about 2 mm. breadth.

Of course when the slit is vertical then rays of light can pass only through the vertical meridian of the cornea; and when the slit is horizontal then rays of light can pass only through the horizontal meridian of the cornea.

We now gently rotate the disc until we bring it into such a position as gives the best distant vision of the test types.

147. The direction of the slit when the best distant vision is obtained will point out the direction of the most emmetropic meridian. We will suppose this to be the horizontal meridian.

148. With the slit then in the horizontal position we note whether the vision is normal, for if V. = $\frac{6}{6}$, and it is not impaired when a low + sphere is placed before it, then we know that the horizontal meridian is emmetropic.

Having proved the horizontal meridian to be

emmetropic we now rotate the disc so as to bring the slit into the vertical position, thereby bringing the vertical meridian to the test, and if it does not equal $\frac{6}{6}$ we then know that the vertical meridian is erroneous and we proceed to correct it, first noting its vision for the distant type and for the clock face.

Suppose we find, say:

(1) V. = $\frac{6}{18}$.

(2) Vertical lines of the clock are dark.

(3) Horizontal lines of the clock are indistinct.

Then, since the horizontal meridian is emmetropic, as shown by **148**, and confirmed by the indistinctness of the horizontal lines, and since the vertical meridian is erroneous, as shown by V. = $\frac{6}{18}$ and by the distinct vertical lines on the clock, our opinion will be that we are dealing with a case of simple astigmatism with an erroneous vertical meridian.

We now proceed to correct the vertical meridian, and keeping the slit vertically in the direction of the erroneous meridian we place a convex sphere, say + 1 D., in front of it with the result that now:

(1) V. = $\frac{6}{36}$ instead of $\frac{6}{18}$, so vision has been made worse.

(2) Vertical lines still more distinct.

The + sphere, therefore, has rendered matters worse.

We therefore try a − sphere, say − 1 D., with the slit still vertical, and we find:

(1) V. = $\frac{6}{9}$ instead of $\frac{6}{18}$, so the lens has improved vision.

(2) Vertical and horizontal lines are about equally indistinct, the vertical having become less distinct and the horizontal more so.

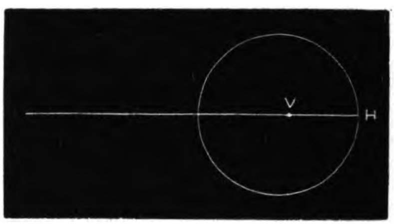
We now try a $-$ 2 D. sphere and find:

(1) V. = $\frac{6}{6}$, *i. e.* is correct.

(2) Vertical and horizontal lines are all equally distinct.

Thus, a $-$ 2 D. sphere, acting through the vertical slit, has corrected the vertical meridian, and consequently a $-$ 2 D. cylinder with axis horizontal will correct this meridian. We have thus proved that the vartical meridian is myopic $-$ 2 D., and as the horizontal meridian was emmetropic, we have been dealing with a case of simple myopic astigmatism with the vertical meridian in front of the horizontal (Fig. 31).

FIG. 31.—SIMPLE MYOPIC ASTIGMATISM.



It will be observed that the principle on which we have proceeded has been to find out the least erroneous meridian, and, if necessary, proceed to correct it, but if we find it emmetropic we then test the meridian which is at right angles to the emmetropic one. And if astigmatism exists this meridian must be erroneous;

and we are dealing with a case of simple astigmatism, but whether it is simple myopic or simple hypermetropic is of course decided by noting that lens which, acting on the erroneous meridian, renders vision normal.

149. Hence our rules will be :

(1) By means of the slit find out the least erroneous meridian, and if vision is not normal then proceed to correct the meridian by means of + or − spheres.

(2) Note the number of dioptres of the correcting sphere.

(3) Rotate the slit so as to place its direction at right angles to the least erroneous meridian; consequently the slit will now be in the direction of the *most* erroneous meridian; then proceed to correct this meridian by means of + or − spheres.

(4) Always commence the correction of any erroneous meridian by using + spheres, and these failing to improve vision, then proceed to use − spheres.

CHAPTER XII

SIMPLE HYPERMETROPIC ASTIGMATISM

150. Suspecting astigmatism, for the reasons given in Section **145**, we proceed as in Section **146**, and test the eye with test type, and find, say:

$V. = \frac{6}{24}$.

With the clock we find:

Vertical lines indistinct.

Horizontal (9 o'clock to 3 o'clock) distinct.

From this we learn:

(1) That the vertical meridian is emmetropic.

(2) That the horizontal meridian is in error; the distinct lines showing that it deviates more from emmetropia than does the vertical meridian.

Now fix the stenopaic slit and rotate it so as to bring it into such a position as gives the most distinct vision of the distant test type.

151. The direction of the slit will point out the direction of the most emmetropic meridian. We will suppose this to be the vertical one.

We therefore fix the slit in a vertical position and note whether vision is normal; for if $V. = \frac{6}{6}$, and

it is not impaired when a low + sphere is placed before it, then we know that the vertical meridian is emmetropic.

Having proved the vertical meridian to be emmetropic, we then proceed to test the horizontal by bringing the slit into a horizontal position.

Suppose we find, with the slit horizontal:

(1) V. = $\frac{6}{24}$.

(2) Vertical lines of clock indistinct.

(3) Horizontal dark.

Then, since the vertical meridian is emmetropic, as shown by V=$\frac{6}{6}$ and confirmed by the indistinctness of the vertical lines, and since the horizontal meridian is erroneous, as shown by V. = $\frac{6}{24}$ and by the dark horizontal lines on the clock, our opinion will be that we have before us a case of simple astigmatism with an erroneous horizontal meridian.

We now proceed to correct this erroneous horizontal meridian. Keeping the slit then in the direction of the horizontal meridian we place a convex sphere, say +1 D., in front of it, with the result that:

(1) V. = $\frac{6}{12}$, so the lens has improved vision.

(2) Vertical lines less indistinct.

(3) Horizontal lines less dark and distinct.

We now, since a + 1 D. sphere improved vision, try a + 2 D. sphere, and find:

(1) V. = $\frac{6}{6}$, *i.e.* is correct.

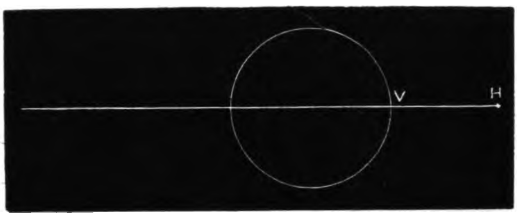
(2) Vertical and horizontal lines are all equally distinct.

Thus a + 2 D. sphere acting through the horizontal slit has corrected the horizontal meridian, and

consequently a + 2 D. cylinder axis vertical will correct the horizontal meridian.

We have now proved that the horizontal meridian is hypermetropic + 2 D., and as the vertical was emmetropic we have been dealing with a case of simple hypermetropic astigmatism with the focus of the horizontal meridian behind that of the vertical (Fig. 32).

FIG. 32.—SIMPLE HYPERMETROPIC ASTIGMATISM.



CHAPTER XIII

COMPOUND MYOPIC ASTIGMATISM

152. Suspecting the presence of astigmatism, for reasons given in Section **145**, with the test type we find:

V. = $\frac{6}{36}$, badly.

With the clock:

Vertical lines dark and distinct.

Horizontal indistinct.

From this we learn:

(1) That the vertical meridian is erroneous.

(2) That the horizontal meridian is emmetropic, or all events that the vertical meridian which shows the most distinct lines, deviates more from emmetropia than does the horizontal meridian.

With the slit horizontal V. = $\frac{6}{18}$.

With the slit vertical V. = $\frac{6}{60}$.

Therefore, this again tells us that the horizontal meridian is the *least* erroneous of the two; and therefore that the meridian at right angles to it, viz. the vertical, is the most erroneous.

Then fixing the slit horizontally we proceed to correct the horizontal least erroneous meridian.

We find that with the slit horizontal:

V. = $\frac{6}{18}$.

We then try a + 1 D. sphere, and find:

V. = $\frac{6}{60}$, *i.e.* the error is made worse.

So we try a − 1 D. sphere, and with it:

(1) V. = $\frac{6}{9}$.

(2) Vertical and horizontal lines are all fairly distinct.

With a − 2 D. sphere, we find:

(1) V. = $\frac{6}{6}$.

(2) All lines of the clock equally distinct and clear.

Therefore a − 2 D. sphere has corrected the horizontal meridian, which consequently had − 2 D. of myopia.

Then fixing the slit vertically (in the direction of the most erroneous meridian) we find:

(1) V. = $\frac{6}{60}$.

(2) Vertical lines darkest and most distinct.

(3) Horizontal lines indistinct.

Keeping the slit vertically we proceed to correct the vertical meridian.

We place a + 1 D. sphere in the frame and find that no type is visible. Therefore the + lens has made vision worse.

Consequently we fix − 1 D., and find now:

(1) V. = $\frac{6}{24}$, *i.e.* vision is improved.

(2) Vertical lines dark and distinct.

Horizontal less indistinct.

We change now to − 2 D. sphere, and find:

(1) V. = $\frac{6}{18}$, *i.e.* still more improved.

(2) Vertical lines dark and distinct.

Horizontal lines still less indistinct.

A − 3 sphere effects still further improvement, for with it:

(1) V. = $\frac{6}{9}$.

(2) Vertical and horizontal lines are all fairly distinct.

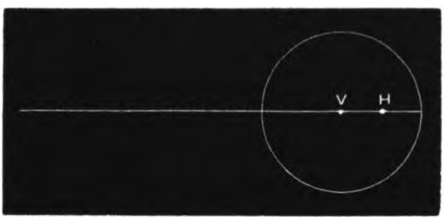
And a − 4 D. sphere makes:

(1) V. = $\frac{6}{6}$.

153. Vertical and horizontal lines all clear and distinct. Therefore a − 4 D. sphere has corrected the vertical meridian, which consequently had − 4 D. of myopia; and we have seen that the horizontal meridian had − 2 D. of myopia.

Therefore, both meridians being myopic, we have

FIG. 33.—COMPOUND MYOPIC ASTIGMATISM.



been dealing with a case of compound myopic astigmatism with:

Vertical meridian = − 4 D.

Horizontal meridian = − 2 D.

Which would be written thus, supposing that the right eye has been tested:

−4 D.
R. ——|——−2 D.

The cross lines representing the two meridians.

And supposing that the amounts of error in the two meridians remained the same after that we had paralysed the accommodation with atropine, we should correct the errors as follows: we should correct the least erring meridian with a sphere, and the other with a cylinder; therefore in this case our correction would be − 2 D. sphere ⊃* − 2 D. cylinder axis horizontal.

It is evident that the − 2 D. sphere fully corrects the horizontal meridian, and also will at the same time correct 2 D. out of the 4 D. of the myopia of the vertical, leaving only 2 dioptres (instead of 4 D.) of the vertical to be corrected by the cylinder.

A little consideration will show why in such a case we should fail to materially improve vision by the spheres alone.

For a − 2 D. sphere would fully correct the horital, and would partially correct the vertical.

A − 3 D. sphere would still further improve the vertical meridian, but would have over corrected the horizontal myopic meridian so that it would have become hypermetropic + 1 D.

A − 4 D. sphere would have fully corrected the vertical meridian, but would have increased the over correction of the horizontal meridian which would have become hypermetropic + 2 D.

* ⊃ means combined with.

CHAPTER XIV

COMPOUND HYPERMETROPIC ASTIGMATISM

154. Suspecting the presence of astigmatism, for reasons given in Section **145**, with the test type we find:

(1) $V = \frac{6}{60}$.

With the clock:

(2) Vertical lines indistinct.

Horizontal somewhat darker.

From this we learn that the horizontal meridian which shows the most distinct lines deviates more from emmetropia than does the vertical meridian.

With the slit vertical, $V. = \frac{6}{18}$.

With the slit horizontal, $V. = \frac{6}{60}$, badly.

Clearly, then, the vertical meridian is the least in error and therefore the horizontal is the most erroneous.

Then fixing the slit vertically we proceed to correct the vertical least erroneous meridian. We find:

(1) $V. = \frac{6}{18}$.

(2) Vertical lines dark and distinct.

(3) Horizontal lines indistinct.

With a + 1 D. sphere we find:

(1) $D. = \frac{6}{12}$.

(2) Vertical lines dark.

(3) Horizontal getting darker.

Therefore a + 1 D. sphere improves vision, so we try a + 2 sphere and we find :

(1) V = $\frac{6}{6}$.

(2) Vertical and horizontal lines equally clear and distinct.

Therefore a + 2 D. sphere has corrected the vertical meridian, which consequently had + 2 D. of hypermetropia.

Then fixing the slit horizontally we find :

(1) V = $\frac{6}{60}$ badly.

(2) Vertical lines almost invisible.

(3) Horizontal lines dark.

Keeping the slit horizontal, we proceed to correct the horizontal meridian.

We place a + 1 D. sphere in the trial frame and find :

(1) V = $\frac{6}{60}$.

(2) Vertical lines less indistinct.

(3) Horizontal lines dark.

With a + 3 D. sphere we find :

(1) V. = $\frac{6}{9}$.

(2) Vertical lines becoming darker.

(3) Horizontal lines still dark.

Therefore the + 3 D. sphere has improved vision.

With a + 4 D. sphere we find :

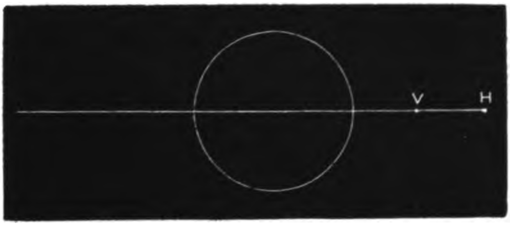
(1) V = $\frac{6}{6}$.

(2) Vertical and horizontal lines clear and distinct.

155. Therefore a + 4 D. sphere has corrected the horizontal meridian, which consequently had + 4 D. of

hypermetropia; and we have seen that the vertical meridian had + 2 D. of hypermetropia, and therefore, since both the meridians are hypermetropic, we have

FIG. 34.—COMPOUND HYPERMETROPIC ASTIGMATISM.



been correcting a case of compound hypermetropic astigmatism with:

Vertical meridian = + 2 D.
Horizontal meridian = + 4 D.

Which would be written thus, supposing that the right eye has been tested:

|+2 D.
R. —|—+4 D.

The cross lines representing the meridians.

And supposing that the amount of error in the two meridians remained the same after that we had paralysed the accommodation with atropine, we should correct the errors as follows; we should correct the least erroneous meridian by a sphere and the other by a cylinder, and therefore, in this case, the correction would be + 2 D. sphere ⊂⊃ + 2 D. cylinder axis vertical.

It is evident that the + 2 D. sphere will fully correct

the vertical meridian, and also will at the same time correct 2 D. out of the 4 D. of the hypermetropia of the horizontal meridian, leaving only 2 dioptres (instead of 4 D.) of the horizontal to be corrected by the cylinder.

It is evident also that no sphere alone would have materially improved vision, because the two meridians require unequal corrections, but a sphere of course would alter all meridians to an equal extent.

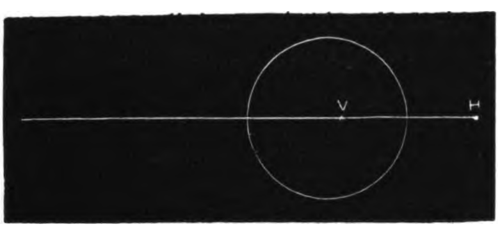
CHAPTER XV

MIXED ASTIGMATISM

156. We have hitherto dealt with cases of astigmatism in which one meridian has been more erroneous than the other. We will now consider a case of mixed astigmatism in which the two meridians may be equally faulty, one being myopic and the other hypermetropic. Of course, if they were either equally myopic or equally hypermetropic, we should not have any astigmatism, but the case would be one of ordinary myopia or ordinary hypermetropia.

Suppose the vertical meridian is myopic − 2 D.,

FIG. 35.—MIXED ASTIGMATISM.



and the horizontal meridian hypermetropic + 2 D., in such a case vision would be equally faulty whether

the vertical or the horizontal meridian is tested, and therefore we cannot follow out our plan of correcting the least faulty meridian first, inasmuch as the errors in each are of the same degree. It remains therefore in such a case to select one meridian and correct that one, doing the same afterwards with the other meridian.

We will first take the vertical meridian, placing the slit vertically, and fixing + 1 D. sphere in the frame we find:

$V = \frac{6}{36}$.

With + 2 D. letters are hardly visible. Therefore a + lens makes vision worse.

With − 1 D. sphere we find:

(1) $V. = \frac{6}{9}$.

(2) Vertical and horizontal lines are fairly dark; horizontal the darker.

With − 2 D. sphere we find:

(1) $V. = \frac{6}{6}$.

(2) Vertical and horizontal lines all equally distinct.

Therefore the vertical meridian is corrected by − 2 D. sphere.

Now place the slit horizontally and we find that + 1 D. sphere improves the vision and that + 2 D. sphere renders:

(1) $V. = \frac{6}{6}$.

(2) Vertical and horizontal lines equally clear and distinct.

Thus the vertical meridian is corrected by a − 2 D. sphere and the horizontal by a + 2 D. sphere.

157. One meridian, therefore, has − 2 D. of myopia

and the other + 2 D. of hypermetropia, and we have been correcting a case of mixed astigmatism with:

Vertical meridian = − 2 D.

Horizontal meridian = + 2 D.

Which would be written thus, supposing that the right eye has been tested:

$$\text{R.}\quad \begin{array}{c|l} & -2\text{ D.} \\ \hline & +2\text{ D.} \end{array}$$

The cross lines representing the meridians.

And if, when under the influence of atropine, the meridians still showed the same amount of error, and if we followed our usual plan, we should correct the least erroneous meridian by a sphere and the other by a cylinder. But in this case the meridians are equally erroneous.

Therefore it will serve to illustrate another rule, viz.:

158. If possible order a − cylinder to be ground on to a + sphere, rather than a + cylinder to be ground on to a − sphere.

Therefore our prescription for the optician would be + 2 D. sphere $\bigcirc$ − 4 D. cylinder axis horizontal.

It is almost self-evident why it was that no sphere alone was found to improve vision to any extent, because in the same proportion as a + sphere improved the horizontal meridian, just in the same degree did it make the vertical more erroneous; and with a − sphere the vertical was improved at the expense of the horizontal.

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